

WT-74

AD636766

# Operation UPSHOT-KNOTHOLE

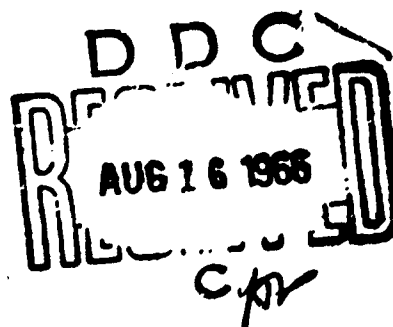
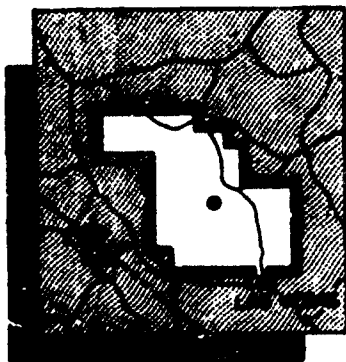
## NEVADA PROVING GROUNDS

March - June 1953

Project 3.29

BLAST EFFECTS OF ATOMIC WEAPONS  
UPON CURTAIN WALLS AND PARTITIONS  
OF MASONRY AND OTHER MATERIALS

Issuance Date: April 21, 1959



HEADQUARTERS FIELD COMMAND, ARMED FORCES SPECIAL WEAPONS PROJECT  
SANDIA BASE, ALBUQUERQUE, NEW MEXICO

CLEARANCE			
FOR FEDERAL SCIENTIFIC AND TECHNICAL INFORMATION			
Hardcopy	Microfilm		
\$24.80	\$1.50	270	82
ARCHIVE COPY			

Inquiries relative to this report may be made to  
Chief, Armed Forces Special Weapons Project  
Washington, D. C.

DISTRIBUTION OF THIS DOCUMENT IS  
UNLIMITED.

DO NOT RETURN THIS DOCUMENT

ACCESSION No.	
CFSTI	WHITE SEC (P) <input checked="" type="checkbox"/>
DDC	DIFF SEC (P) <input type="checkbox"/>
UNANNOUNCED	<input checked="" type="checkbox"/>
JUSTIFICATION	<i>for statement</i>
BY	<i>RM</i>
DISTRIBUTION/AVAILABILITY CODES	
INT.	AVAIL. and/or SPECIAL
1	

**OPERATION UPSHOT-KNOTHOLE**

Project 329

**BLAST EFFECTS OF ATOMIC WEAPONS  
UPON CURTAIN WALLS AND PARTITIONS  
OF MASONRY AND OTHER MATERIALS**

Report to the Test Director

by

Benjamin C. Taylor

August 1956

Federal Civil Defense Administration  
Battle Creek, Michigan

## ABSTRACT

Blast-resistance tests were made during Shot 9 on various types of wall panels and interior partitions. Buildings 3.29a, b, c, and d were rectangular test cells, open at the front and rear, having reinforced-concrete floor slabs, roof slabs, and dividing walls. Windowless test wall panels were built into the cell openings of Building 3.29a and 3.29c for the full height and width. The cells of Buildings 3.29b and 3.29d contained interior test partitions of many types and were enclosed with windowed masonry walls in front and solid masonry walls at the rear. Two ranges were selected for each of the building types, one at about 4.5-psi peak side-on overpressure and the other at about 7.5-psi peak side-on overpressure, in order to bracket the collapse overpressure levels for the standard construction of the test panels and partitions.

The test was originally planned for comparative purposes. Subsequently, it became possible to provide some instrumentation, but not enough for a detailed analysis. Interior pressures were not recorded and the rear wall loadings had to be estimated for the analysis. The orientation of the cells to the shot was not as expected, possibly affecting the results to some degree. Laboratory tests of the component wall materials were not complete, and estimates had to be made of certain of these properties. Also, variation in the quality of construction of the test wall panels probably affected the results.

Numerical integration was used for computation of wall response. Adjustments were made to the unknown variables to correlate the theoretical and observed results.

Motion picture records were obtained at a rate of 64 frames per second, and selected frame sequences are included. The heavy dust conditions made many of the pictures unusable.

Table 3.8 lists estimated maximum overpressure levels for collapse of panels constructed of the various materials as determined from these tests.



## FOREWORD

This report is one of the reports presenting the results of the 78 projects participating in the Military Effects Tests Program of Operation Upshot-Knothole, which included 11 test detonations. For readers interested in other pertinent test information, reference is made to WT-782, "Summary Report of the Technical Director", Military Effects Program. This summary report includes the following information of possible general interest: (1) An overall description of each detonation, including yield, height of burst, ground zero location, time of detonation, ambient atmospheric conditions at detonation, etc., for the 11 shots; (2) Compilation and correlation of all project results on the basic measurements of blast and shock, thermal radiation, and nuclear radiation; (3) Compilation and correlation of the various project results on weapons effects; (4) A summary of each project, including objectives and results; and (5) A complete listing of all reports covering the Military Effects Tests Program.

## PREFACE

The purpose of this report is to acquaint those persons concerned with building design and construction with the relative strengths of various conventional types of curtain walls and interior partitions exposed to the blast effect of nuclear weapons.

The author wishes to acknowledge the excellent assistance given him in the postshot evaluation of results by the following men who constitute the Project Evaluation Team: Frederic A. Pawley, Research Secretary, American Institute of Architects; Dr. Linton E. Grinter, Dean of the Graduate School and Director of Research, University of Florida (Consultant to the Federal Civil Defense Administration); Dr. Thomas C. Kavanagh, Chairman, Department of Civil Engineering, New York University (Consultant to the Federal Civil Defense Administration); Abraham S. Neiman, Technical Branch, Engineering Division, Federal Civil Defense Administration; and Joseph B. Byrnes, Technical Branch, Engineering Division, Federal Civil Defense Administration.

The analysis of the results of these tests and the preparation of Chapters 2 and 3 of this report were performed by Ammann and Whitney, Consulting Engineers, of New York City, under contract with the Federal Civil Defense Administration.

Mr. John P. Lynch, Structural Engineer, Engineering Office, Federal Civil Defense Administration, reviewed and commented upon the draft of Chapters 2 and 3, as prepared by Ammann and Whitney, prior to their preparation in final form.

## CONTENTS

ABSTRACT -----	5
FOREWORD -----	6
PREFACE -----	7
CHAPTER 1 INTRODUCTION -----	19
1.1 Objective -----	19
1.2 Experiment Design -----	19
CHAPTER 2 RESULTS -----	29
2.1 Pressures -----	29
2.2 Structural Results -----	29
CHAPTER 3 DISCUSSION -----	237
3.1 Curtain Wall Structures, 3.29a and 3.29c -----	237
3.2 Interior Partition Test Structures, 3.29b and 3.29d -----	254
3.3 Fundamental Frequency Comparisons -----	268
3.4 Conclusions and Recommendations -----	268
REFERENCES -----	274
TABLES	
3.1 Tabulation of Recorded and Calculated Values of Maximum Displacements of Curtain Walls, Buildings 3.29 a and c -----	240
3.2 Tabulation of Observed and Calculated Behavior of Front Curtain Walls, Buildings 3.29 b and d -----	255
3.3 Tabulation of Observed and Calculated Behavior of Front Interior Partitions, Buildings 3.29 b and d -----	256
3.4 Tabulation of Observed and Calculated Behavior of Rear Interior Partitions, Buildings 3.29 b and d -----	257
3.5 Tabulation of Observed and Calculated Behavior of Rear Curtain Walls, Buildings 3.29 b and d -----	258
3.6 Summary of Fundamental Frequencies of Front and Rear Walls, Buildings 3.29 a and c -----	269
3.7 Summary of Fundamental Frequencies of Front and Rear Walls, Buildings 3.29 b and d -----	269
3.8 Maximum Overpressures Which the Various Types of Windowless Test Panels May Be Expected to Resist in a One-Story Structure ---	270

## FIGURES

1.1 Test cell structure No. 3.29a, curtain wall tests at 6,650 feet from ground zero; general view of front of structure before blast-----	20
1.2 Test cell structure No. 3.29a, curtain wall tests at 6,650 feet from ground zero; general view of front of structure after blast-----	20
1.3 Test cell structure No. 3.29a, curtain wall tests at 6,650 feet from ground zero; general view of rear of structure before blast-----	21
1.4 Test cell structure No. 3.29a, curtain wall tests at 6,650 feet from ground zero; general view of rear of structure after blast-----	21
1.5 Test cell structure No. 3.29b, interior partition tests at 6,600 feet from ground zero; general view of front of structure before blast-----	22
1.6 Test cell structure No. 3.29b, interior wall tests at 6,600 feet from ground zero; general view of front of structure after blast-----	22
1.7 Test cell structure No. 3.29b, interior partition tests at 6,600 feet from ground zero; general view of rear of structure before blast-----	23
1.8 Test cell structure No. 3.29b, interior partition tests at 6,600 feet from ground zero; general view of rear of structure after blast-----	23
1.9 Test cell structure No. 3.29c, curtain wall tests at 4,450 feet from ground zero; general view of front of structure before blast-----	24
1.10 Test cell structure No. 3.29c, curtain wall tests at 4,450 feet from ground zero; general view of front of structure after blast-----	24
1.11 Test cell structure No. 3.29c, curtain wall tests at 4,450 feet from ground zero; general view of rear of structure before blast-----	25
1.12 Test cell structure No. 3.29c, curtain wall tests at 4,450 feet from ground zero; general view of rear of structure after blast-----	25
1.13 Test cell structure No. 3.29d, interior partition tests at 4,350 feet from ground zero; general view of front of structure before blast-----	26
1.14 Test cell structure No. 3.29d, interior partition tests at 4,350 feet from ground zero; general view of front of structure after blast-----	26
1.15 Test cell structure No. 3.29d, interior partition tests at 4,350 feet from ground zero; general view of rear of structure before blast-----	27
1.16 Test cell structure No. 3.29d, interior partition tests at 4,350 feet from ground zero; general view of rear of structure after blast-----	27

2.1 Air pressure, surface level, range 6,625 feet-----	30
2.2 Air pressure, surface level, range 4,400 feet-----	30
2.3 Pressure versus time, front, Building 3.29a-----	31
2.4 Pressure versus time, front, Building 3.29c-----	31
2.5 Pressure versus time, roof, Building 3.29c-----	32
2.6 Rear wall pressure, Building 3.29a-----	33
2.7 Rear wall pressure, Building 3.29c-----	33
2.8 Key planes and elevations, Buildings 3.29a-----	34
2.9 Preshot photography, cell No. 1a-----	36
2.10 Postshot photography, cell No. 1a-----	36
2.11 Preshot photography, cell No. 2a-----	38
2.12 Postshot photography, cell No. 2a-----	38
2.13 Motion picture sequence, front wall, cell No. 2a-----	39
2.14 Preshot photography, cell No. 3a-----	41
2.15 Postshot photography, cell No. 3a-----	41
2.16 Preshot photography, cell No. 4a-----	43
2.17 Postshot photography, cell No. 4a-----	43
2.18 Preshot photography, cell No. 5a-----	45
2.19 Postshot photography, cell No. 5a-----	45
2.20 Motion picture sequence, front wall, cell No. 5a-----	46
2.21 Preshot photography, cell No. 6a-----	48
2.22 Postshot photography, cell No. 6a-----	48
2.23 Preshot photography, cell No. 7a-----	50
2.24 Postshot photography, cell No. 7a-----	50
2.25 Motion picture sequence, front wall, cell No. 7a-----	51
2.26 Preshot photography, cell No. 8a-----	53
2.27 Postshot photography, cell No. 8a-----	53
2.28 Motion picture sequence, front wall, cell No. 8a-----	54
2.29 Preshot photography, cell No. 9a-----	56
2.30 Postshot photography, cell No. 9a-----	56
2.31 Motion picture sequence, front wall, cell No. 9a-----	57
2.32 Preshot photography, cell No. 10a-----	59
2.33 Postshot photography, cell No. 10a-----	59
2.34 Preshot photography, cell No. 11a-----	61
2.35 Postshot photography, cell No. 11a-----	61
2.36 Preshot photography, cell No. 12a-----	63
2.37 Postshot photography, cell No. 12a-----	63
2.38 Preshot photography, cell No. 13a-----	65
2.39 Postshot photography, cell No. 13a-----	65
2.40 Motion picture sequence, front wall, cell No. 13a-----	66
2.41 Preshot photography, cell No. 14a-----	68
2.42 Postshot photography, cell No. 14a-----	68
2.43 Rear wall, cell No. 15a-----	70
2.44 Rear wall, cell No. 16a-----	72
2.45 Rear wall, cell No. 17a-----	74
2.46 Rear wall, cell No. 18a-----	76
2.47 Preshot photography, cell No. 1b-----	78
2.48 Postshot photography, cell No. 1b-----	78
2.49 Postshot, interior, cell No. 1b-----	79
2.50 Postshot, interior, cell No. 1b-----	79

2.51	Preshot photography, cell No. 2b	81
2.52	Postshot photography, cell No. 2b	81
2.53	Postshot, rear wall, interior, cell No. 2b	82
2.54	Postshot, interior, cell No. 2b	82
2.55	Preshot photography, cell No. 3b	84
2.56	Postshot photography, cell No. 3b	84
2.57	Postshot, front wall detail, cell No. 3b	85
2.58	Postshot, interior, cell No. 3b	85
2.59	Preshot photography, cell No. 4b	87
2.60	Postshot photography, cell No. 4b	87
2.61	Postshot, interior, cell No. 4b	88
2.62	Preshot photography, cell No. 5b	90
2.63	Postshot photography, cell No. 5b	90
2.64	Postshot, interior, cell No. 5b	91
2.65	Postshot, interior, cell No. 5b	91
2.66	Preshot photography, cell No. 6b	93
2.67	Postshot photography, cell No. 6b	93
2.68	Postshot, interior, cell No. 6b	94
2.69	Preshot photography, cell No. 7b	96
2.70	Postshot photography, cell No. 7b	96
2.71	Postshot, interior, cell No. 7b	97
2.72	Preshot photography, cell No. 8b	99
2.73	Postshot photography, cell No. 8b	99
2.74	Postshot, interior, cell No. 8b	100
2.75	Preshot photography, cell No. 9b	102
2.76	Postshot photography, cell No. 9b	102
2.77	Postshot, interior, cell No. 9b	103
2.78	Preshot photography, cell No. 10b	105
2.79	Postshot photography, cell No. 10b	105
2.80	Preshot photography, cell No. 11b	107
2.81	Postshot photography, cell No. 11b	107
2.82	Postshot, interior, small room, cell No. 11b	108
2.83	Postshot, interior, cell No. 11b	109
2.84	Postshot, door detail, cell No. 11b	109
2.85	Preshot photography, cell No. 12b	111
2.86	Postshot photography, cell No. 12b	111
2.87	Postshot, interior, cell No. 12b	112
2.88	Preshot photography, cell No. 13b	114
2.89	Postshot photography, cell No. 13b	114
2.90	Postshot, interior, cell No. 13b	115
2.91	Preshot photography, cell No. 14b	117
2.92	Postshot photography, cell No. 14b	117
2.93	Postshot, interior, cell No. 14b	118
2.94	Preshot photography, cell No. 15b	120
2.95	Postshot photography, cell No. 15b	120
2.96	Postshot, interior, cell No. 15b	121
2.97	Postshot, front wall detail, cell No. 15b	121
2.98	Preshot photography, cell No. 16b	123
2.99	Postshot photography, cell No. 16b	123
2.100	Postshot, interior, cell No. 16b	124

2.101	Preshot photography, cell No. 1c-----	126
2.102	Postshot photography, cell No. 1c-----	126
2.103	Motion picture sequence, front wall, cell No. 1c-----	127
2.104	Postshot, interior, front wall, cell No. 1c-----	128
2.105	Postshot, front wall detail, cell No. 1c-----	128
2.106	Postshot, front wall detail, cell No. 1c-----	129
2.107	Postshot, interior, cell No. 1c-----	129
2.108	Preshot photography, cell No. 2c-----	131
2.109	Postshot photography, cell No. 2c-----	131
2.110	Motion picture sequence, front wall, cell No. 2c-----	132
2.111	Preshot photography, cell No. 3c-----	134
2.112	Postshot photography, cell No. 3c-----	134
2.113	Preshot photography, cell No. 4c-----	136
2.114	Postshot photography, cell No. 4c-----	136
2.115	Preshot photography, cell No. 5c-----	138
2.116	Postshot photography, cell No. 5c-----	138
2.117	Motion picture sequence, front wall, cell No. 5c-----	139
2.118	Preshot photography, cell No. 6c-----	141
2.119	Postshot photography, cell No. 6c-----	141
2.120	Motion picture sequence, front wall, cell No. 6c-----	142
2.121	Postshot, front wall detail, cell No. 6c-----	143
2.122	Postshot, interior, front wall, cell No. 6c-----	143
2.123	Preshot photography, cell No. 7c-----	145
2.124	Postshot photography, cell No. 7c-----	145
2.125	Preshot photography, cell No. 8c-----	147
2.126	Postshot photography, cell No. 8c-----	147
2.127	Postshot, rear wall detail, cell No. 8c-----	148
2.128	Preshot photography, cell No. 9c-----	150
2.129	Postshot photography, cell No. 9c-----	150
2.130	Motion picture sequence, front wall, cell No. 9c-----	149
2.131	Preshot photography, cell No. 10c-----	152
2.132	Postshot photography, cell No. 10c-----	152
2.133	Motion picture sequence, front wall, cell No. 10c-----	153
2.134	Postshot, front wall detail, cell No. 10c-----	153
2.135	Preshot photography, cell No. 11c-----	155
2.136	Postshot photography, cell No. 11c-----	155
2.137	Motion picture sequence, front wall, cell No. 11c-----	154
2.138	Preshot photography, cell No. 12c-----	157
2.139	Postshot photography, cell No. 12c-----	157
2.140	Motion picture sequence, front wall, cell No. 12c-----	156
2.141	Postshot, front wall detail, cell No. 12c-----	158
2.142	Postshot, front wall detail, cell No. 12c-----	158
2.143	Preshot photography, cell No. 13c-----	160
2.144	Postshot photography, cell No. 13c-----	160
2.145	Postshot, interior, cell No. 13c-----	161
2.146	Postshot, rear wall detail, cell No. 13c-----	161
2.147	Preshot photography, cell No. 14c-----	163
2.148	Postshot photography, cell No. 14c-----	163
2.149	Preshot photography, cell No. 15c-----	165
2.150	Postshot photography, cell No. 15c-----	165

2.151	Motion picture sequence, front wall, cell No. 15c-----	166
2.152	Postshot, front wall detail, cell No. 15c-----	167
2.153	Postshot, front wall detail, cell No. 15c-----	167
2.154	Rear wall, cell No. 16c-----	169
2.155	Postshot, interior, cell No. 16c-----	169
2.156	Rear wall, cell No. 17c-----	171
2.157	Postshot, rear wall detail, cell No. 17c-----	171
2.158	Rear wall, cell No. 18c-----	173
2.159	Postshot, interior, rear wall, cell No. 18c-----	173
2.160	Preshot photography, cell No. 1d-----	175
2.161	Postshot photography, cell No. 1d-----	175
2.162	Postshot, interior, cell No. 1d-----	176
2.163	Preshot photography, cell No. 2d-----	178
2.164	Postshot photography, cell No. 2d-----	178
2.165	Postshot, interior, cell No. 2d-----	179
2.166	Postshot, interior, cell No. 2d-----	179
2.167	Preshot photography, cell No. 3d-----	181
2.168	Postshot photography, cell No. 3d-----	181
2.169	Postshot, interior, cell No. 3d-----	182
2.170	Postshot, rear wall detail, cell No. 3d-----	182
2.171	Postshot, front wall detail, cell No. 3d-----	183
2.172	Postshot, front wall detail, cell No. 3d-----	183
2.173	Preshot photography, cell No. 4d-----	185
2.174	Postshot photography, cell No. 4d-----	185
2.175	Postshot, interior, cell No. 4d-----	186
2.176	Postshot, front wall detail, cell No. 4d-----	186
2.177	Preshot photography, cell No. 5d-----	188
2.178	Postshot photography, cell No. 5d-----	188
2.179	Postshot, interior, cell No. 5d-----	189
2.180	Postshot, front wall detail, cell No. 5d-----	189
2.181	Preshot photography, cell No. 6d-----	191
2.182	Postshot photography, cell No. 6d-----	191
2.183	Postshot, interior, cell No. 6d-----	192
2.184	Preshot photography, cell No. 7d-----	194
2.185	Postshot photography, cell No. 7d-----	194
2.186	Postshot, interior, cell No. 7d-----	195
2.187	Postshot, rear wall detail, cell No. 7d-----	195
2.188	Preshot photography, cell No. 8d-----	197
2.189	Postshot photography, cell No. 8d-----	197
2.190	Postshot, interior, cell No. 8d-----	198
2.191	Preshot photography, cell No. 9d-----	200
2.192	Postshot photography, cell No. 9d-----	200
2.193	Postshot, interior, cell No. 9d-----	201
2.194	Preshot photography, cell No. 10d-----	203
2.195	Postshot photography, cell No. 10d-----	203
2.196	Motion picture sequence, front wall, cell No. 10d-----	204
2.197	Postshot, interior, cell No. 10d-----	205
2.198	Preshot photography, cell No. 11d-----	207
2.199	Postshot photography, cell No. 11d-----	207
2.200	Postshot, interior, cell No. 11d-----	208



2.201	Postshot, interior, cell No. 11d	209
2.202	Postshot, interior, small room, cell No. 11d	209
2.203	Preshot photography, cell No. 12d	211
2.204	Postshot photography, cell No. 12d	211
2.205	Postshot, interior, cell No. 12d	212
2.206	Postshot, rear wall detail, cell No. 12d	212
2.207	Preshot photography, cell No. 13d	214
2.208	Postshot photography, cell No. 13d	214
2.209	Postshot, interior, cell No. 13d	215
2.210	Preshot photography, cell No. 14d	217
2.211	Postshot photography, cell No. 14d	217
2.212	Postshot, interior, cell No. 14d	218
2.213	Preshot photography, cell No. 15d	220
2.214	Postshot photography, cell No. 15d	220
2.215	Postshot, interior, cell No. 15d	221
2.216	Postshot, interior, cell No. 15d	221
2.217	Preshot photography, cell No. 16d	223
2.218	Postshot photography, cell No. 16d	223
2.219	Postshot, floor detail, cell No. 16d	224
2.220	Postshot, interior, cell No. 16d	225
2.221	Postshot, ceiling detail, cell No. 16d	225
2.222	Corner detail for front and rear wall, Buildings 3.29a and 3.29c	226
2.223	Closure details for cell openings, Buildings 3.29a, 3.29b, 3.29c and 3.29d	226
2.224	Corner detail for cells No. 16 and 17, rear wall, Buildings 3.29a and 3.29c	227
2.225	Corner and rear wall detail for cell No. 18, Buildings 3.29a and 3.29c	227
2.226	Rear wall detail for cells No. 16 and 17, Buildings 3.29a and 3.29c	228
2.227	Front and rear wall detail for cell No. 14, Buildings 3.29a and 3.29c	228
2.228	Rear wall detail for cell No. 18, Buildings 3.29a and 3.29c	229
2.229	Corner detail for cells No. 1 and 14, front and rear walls, Buildings 3.29a and 3.29c	230
2.230	Top joint detail (bottom similar) for cells No. 5, 10 and 12, front and rear walls, Buildings 3.29a and 3.29c	230
2.231	Corner and front wall detail for cell No. 15, Building 3.29c	231
2.232	Corner and rear wall detail for cell No. 15, Buildings 3.29a and 3.29c	231
2.233	Corner detail for partitions, cell No. 16, Buildings 3.29b and 3.29d	232
2.234	Bottom joint detail (top similar) for partitions, cell No. 16, Buildings 3.29b and 3.29d	232
2.235	Top joint detail (bottom similar) for partitions, cell No. 5, Buildings 3.29b and 3.29d	233
2.236	Partition detail for cell No. 6, Buildings 3.29b and 3.29d	233
2.237	Corner detail for front and rear walls, Buildings 3.29b and 3.29d	234

2.238	Top joint (bottom similar) for front and rear walls, Buildings 3.29b and 3.29d and cells No. 1 to 4, 6 to 11, and 13, Buildings 3.29a and 3.29c -----	234
2.239	Top joint detail (bottom similar) for partitions, cell No. 7, Buildings 3.29b and 3.29d -----	235
2.240	Top joint detail (bottom similar) for partitions, cells No. 1, 2, 3, 4, 8, 9, 10, 12 and 13, Buildings 3.29b and 3.29d -----	235
2.241	Partition detail for cell No. 14, Buildings 3.29b and 3.29d -----	236
2.242	Top joint detail (bottom similar) for partitions, cell No. 15, Buildings 3.29b and 3.29d -----	236
3.1	Comparison of recorded and theoretical front wall pressures, Buildings 3.29c -----	238
3.2	Comparison of recorded and theoretical front wall pressures, Building 3.29a -----	238
3.3	Assumed rear panel net pressure (front panel failed), Building 3.29a, Panel 11R-----	242
3.4	Assumed rear panel net pressure (front panel failed), Building 3.29c, Panel 10R -----	242
3.5	Comparison of recorded and computed deflections, Building 3.29a, Panel 1F -----	243
3.6	Comparison of recorded and computed deflections, Building 3.29c, Panel 1F -----	243
3.7	Comparison of recorded and computed deflections, Building 3.29a, Panel 10F-----	244
3.8	Effect of variation of mortar strength on panel deflection, Building 3.29a, Panel 10F-----	244
3.9	Comparison of recorded and computed deflections, Building 3.29c, Panel 10F-----	245
3.10	Comparison of recorded and computed deflections, Building 3.29a, Panel 11F-----	245
3.11	Comparison of recorded and computed deflections, Building 3.29a, Panel 12F-----	246
3.12	Comparison of recorded and computed deflections, Building 3.29a, Panel 13F-----	246
3.13	Comparison of recorded and computed deflections, Building 3.29a, Panel 14F-----	247
3.14	Comparison of recorded and computed deflections, Building 3.29c, Panel 14F-----	247
3.15	Comparison of recorded and computed deflections, Building 3.29c, Panel 15F-----	248
3.16	Comparison of recorded and computed deflections, Building 3.29c, Panel 10R-----	248
3.17	Comparison of recorded and computed deflections, Building 3.29a, Panel 11R-----	249
3.18	Comparison of recorded and computed deflections, Building 3.29a, Panel 12R-----	249
3.19	Comparison of recorded and computed deflections, Building 3.29c, Panel 14R-----	250
3.20	Comparison of recorded and computed deflections, Building 3.29a, Panel 15R-----	250

3.21	Comparison of recorded and computed deflections, Building 3.29c, Panel 15R-----	259
3.22	Theoretical front wall pressure, Building 3.29d, cell No. 1-----	259
3.23	Theoretical front partition pressure, Building 3.29b, cell No. 1-----	260
3.24	Theoretical rear partition pressure, Building 3.29b, cell No. 1-----	260
3.25	Theoretical front partition pressure, Building 3.29b, cell No. 3-----	261
3.26	Theoretical rear partition pressure, Building 3.29b, cell No. 3-----	261
3.27	Theoretical front partition pressure, Building 3.29b, cell No. 8-----	262
3.28	Theoretical front partition pressure, Building 3.29d, cell No. 8-----	262
3.29	Theoretical front partition pressure, Building 3.29b, cells No. 6 and 9-----	263
3.30	Theoretical front partition pressure, Building 3.29d, cells No. 6 and 9-----	263
3.31	Theoretical rear partition pressure, Building 3.29d, cell No. 9-----	264
3.32	Theoretical rear partition pressure, Building 3.29d, cell No. 10-----	264
3.33	Theoretical rear partition pressure, Building 3.29d, cell No. 11-----	265
3.34	Assumed rear wall net pressure, Building 3.29d, cell No. 1-----	265
3.35	Assumed rear wall net pressure, Building 3.29d, cell No. 10-----	266
3.36	Assumed rear wall net pressure, Building 3.29d, cells No. 7, 12, 13 and 15-----	266
3.37	Resistance function for unreinforced solid masonry panel with rigid supports-----	272
3.38	Resistance function for unreinforced hollow masonry panel with rigid supports-----	272

## Chapter I

# INTRODUCTION

### 1.1 OBJECTIVE

The purpose of these tests was to obtain a measure of the effectiveness of curtain walls and partitions commonly used in conventional, framed building construction in resisting blast pressures acting normal to the wall and partition surfaces, and to confirm predictions as to the resistance and the response of typical walls and partitions to the blast pressures produced by nuclear explosions. A more definite knowledge of the behavior of such curtain walls and partitions under blast is of great value to all persons concerned with building design and construction and, specifically, will serve as a guide in the planning of more effective blast-resistant buildings.

### 1.2 EXPERIMENT DESIGN

These tests were, basically, a portion of an extensive program for the test of structures exposed to nuclear blast prepared for the Federal Civil Defense Administration in March, 1952, by Ammann and Whitney, Consulting Engineers, New York City, New York. The Ammann and Whitney designs for the curtain wall and partition tests were modified to some extent by the FCDA in order to reflect requirements for data developed subsequent to the completion of planning and design under the contract.

In outward appearance, the test structures resembled long, low, narrow buildings, but it should be emphasized that this was in no respect a building test. The tests were of building components only—namely, curtain walls and partitions. The reinforced-concrete framework of cells, open front and back, into which the solid curtain walls were built for test purposes was 303 feet 10 inches in length, 11 feet 2 inches high and 16 feet 0 inches deep. The floor slab was 12 inches thick (8 inches of which was below grade), the roof slab 10 inches thick, and the cell walls 10 inches thick. The structure was divided lengthwise into 18 cells, 16 of which had an inside width of 16 feet 0 inches, one 12 feet 0 inches and one 20 feet 0 inches. The inside height of all cells was the same, 10 feet 0 inches, and the depth 16 feet 0 inches. The front halves of Cells 16, 17 and 18 of the structure at the near range (Building 3.29c) and Cells 15, 16, 17 and 18 of the structure at the far range (Building 3.29a) were devoted to tests under Project 3.5. The use of these cells by Project 3.5 resulted from a mutual effort to eliminate duplication and effect economies in construction for test purposes.

The reinforced-concrete framework of cells, open front and back, into which the windowed curtain walls and partitions were built was similar to that used for the solid curtain wall tests, except that the length was 274 feet 2 inches and the depth 20 feet 0 inches. The structure was divided lengthwise into 16 cells, one having a 20-foot 0-inch inside width and all others 16-foot 0-inch. The inside height of cells was 10 feet 0 inches.

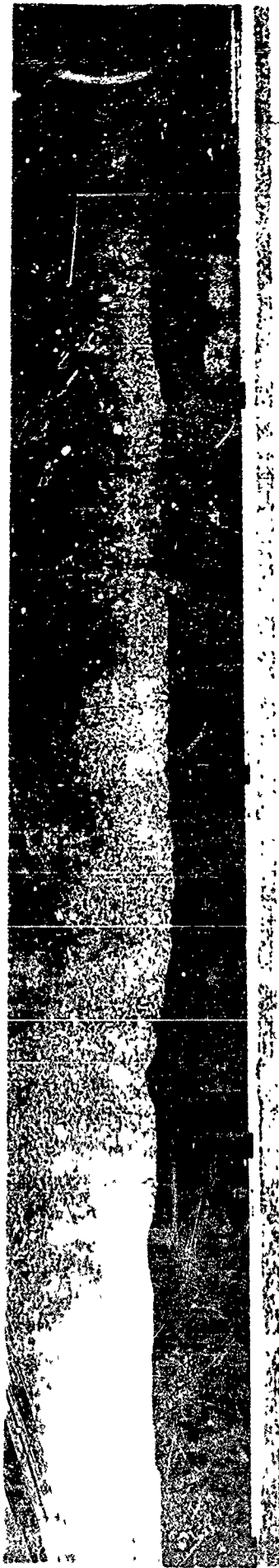


Figure 1.1 Test Cell Structure No. 3.29a, curtain wall tests at 6,650 feet from ground zero; general view of front of structure before blast.

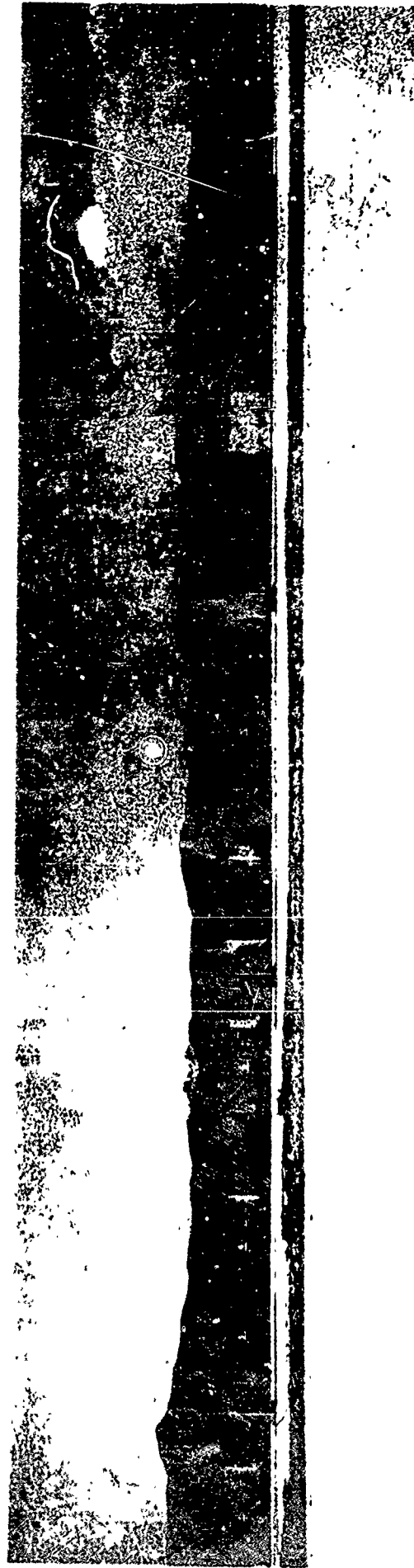


Figure 1.2 Test Cell Structure No. 3.29a, curtain wall tests at 6,650 feet from ground zero; general view of front of structure after blast.

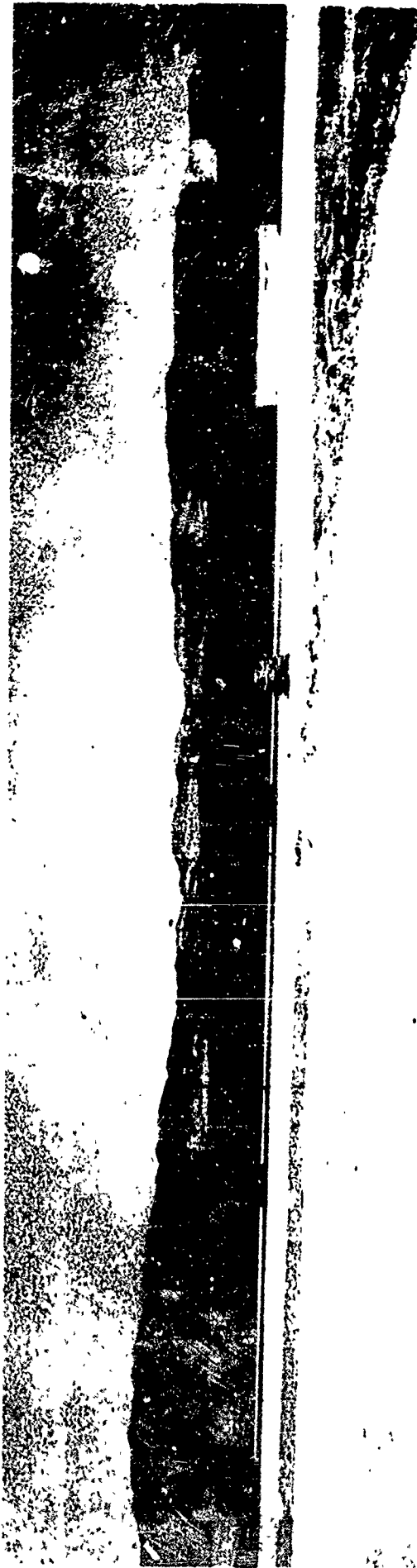


Figure 1.3 Test Cell Structure No. 3.29a, curtain wall tests at 6,650 feet from ground zero; general view of rear of structure before blast.



Figure 1.4 Test Cell Structure No. 3.29a, curtain wall tests at 6,650 feet from ground zero; general view of rear of structure after blast.



Figure 1.5 Test Cell Structure No. 3.29b, interior partition tests at 6,600 feet from ground zero, general view of front of structure before blast.



Figure 1.6 Test Cell Structure No. 3.29b, interior wall tests at 6,600 feet from ground zero; general view of front of structure after blast.



Figure 1.7 Test Cell Structure No. 3.29b, interior partition tests at 6,600 feet from ground zero; general view of rear of structure before blast.



Figure 1.8 Test Cell Structure No. 3.29b, interior partition tests at 6,600 feet from ground zero; general view of rear of structure after blast.





Figure 1.9 Test Cell Structure No. 3.29c, curtain wall tests at 4,450 feet from ground zero; general view of front of structure before blast.



Figure 1.10 Test Cell Structure No. 3.29c, curtain wall tests at 4,450 feet from ground zero; general view of front of structure after blast.

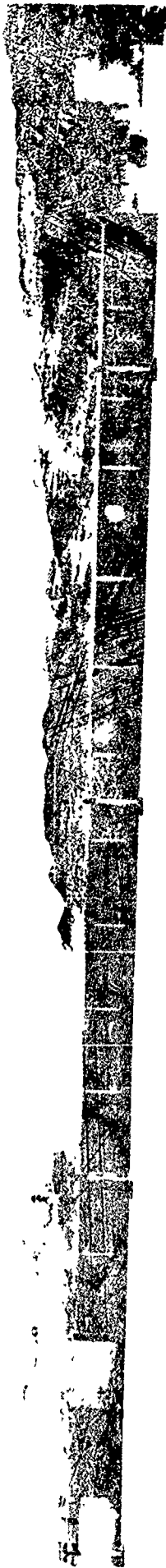


Figure 1.11 Test Cell Structure No. 3.29c, curtain wall tests at 4,450 feet from ground zero; general view of rear of structure before blast.



Figure 1.12 Test Cell Structure No. 3.29c, curtain wall tests at 4,450 feet from ground zero; general view of rear of structure after blast.

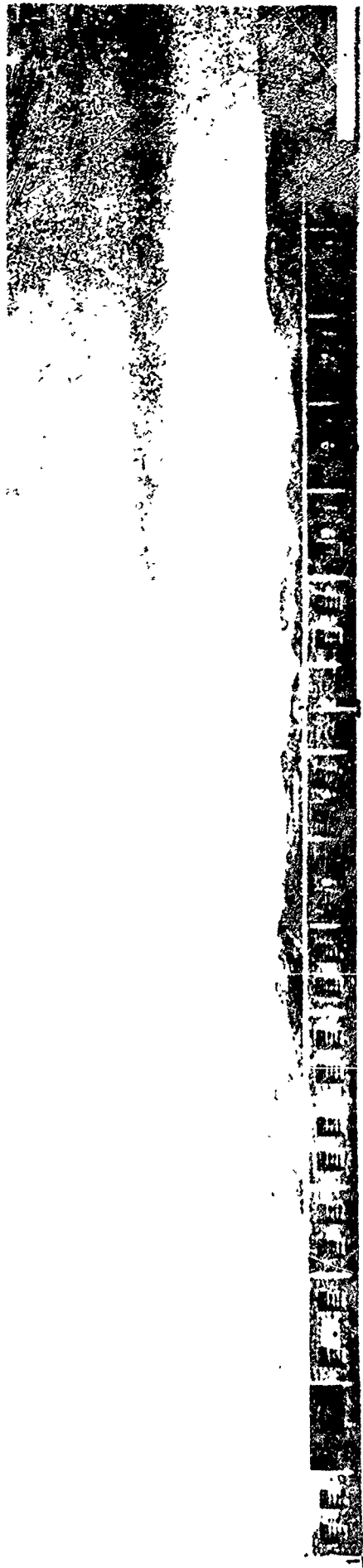


Figure 1.13 Test Cell Structure No. 3.29d, interior partition tests at 4,350 feet from ground zero; general view of front of structure before blast.



Figure 1.14 Test Cell Structure No. 3.29d, interior partition tests at 4,350 feet from ground zero; general view of front of structure after blast.



Figure 1.15 Test Cell Structure No. 3.29d, interior partition tests at 4,350 feet from ground zero; general view of rear of structure before blast.



Figure 1.16 Test Cell Structure No. 3.29d, interior partition tests at 4,350 feet from ground zero; general view of rear of structure after blast.

Access was provided between cells by a 2-foot-by-6-inch-by-3-foot 0-inch opening in each cell wall, with Z-bar and 4-inch timber closure.

One each of the above described test cell structures was located at approximately 6,625 feet from ground zero, and one each at approximately 4,400 feet from ground zero, corresponding to peak overpressures of 4.5 psi and 7.5 psi respectively.

The following types of curtain walls without opening were tested:

- 12-inch solid brick
- 8-inch solid brick
- 12-inch cinder block
- 8-inch cinder block
- 4-inch brick and 4-inch cinder block
- 4-inch brick and 8-inch cinder block
- 4-inch brick and 4-inch clay tile
- 4-inch brick, 2-inch cavity and 8-inch cinder block
- 8-inch reinforced concrete
- 12-inch reinforced grouted brick masonry
- 8-inch reinforced grouted brick masonry
- Corrugated steel
- Corrugated cement-asbestos
- Precast reinforced-concrete channels

The following types of curtain walls with opening were tested:

- 4-inch brick and 8-inch cinder block with 2 windows,  
3 feet 2  $\frac{1}{2}$  inches by 5 feet 4  $\frac{1}{2}$  inches
- 4-inch brick and 8-inch cinder block with 1 window,  
10 feet 8  $\frac{5}{8}$  inches by 5 feet 4  $\frac{1}{2}$  inches
- 4-inch brick and 8-inch cinder block 40 inches high, open above

The following types of interior partitions were tested:

- 4-inch cinder block, plastered both sides
- 8-inch cinder block, plastered both sides
- 2-inch-by-4-inch wood stud partitions, plastered both  
sides on expanded metal lath
- Removable steel glazed partitions
- 2-inch plaster partition on expanded metal lath

The curtain walls and partitions were tested with several different types of edge support, and the partitions were tested singly and in pairs, with and without doors, and with orientations normal to the blast and 90 degrees from normal.

The curtain-wall test-cell structures were instrumented for pressure-time records on the front and rear walls and the roof. Seventeen of the curtain wall panels were instrumented for displacement-time records and two for time-of-break records. This technical instrumentation was provided by Project 3.28.1.

The curtain walls without openings were photographed during the test at a speed of 64 frames per second, and ten of the windowed curtain walls were similarly photographed. This technical photographic coverage was effected with 40 cameras under Project 9.1.

Complete preshot and postshot still photographic coverage, general and detailed, was made. General before-and-after photographs of the test cells are presented in Figures 1.1 through 1.16. Detailed results are presented in Chapter 2.

## Chapter 2

# RESULTS

### 2.1 PRESSURES

The recorded pressure data is shown in Figures 2.1 through 2.7.

The recorded air pressures at the surface level (Figures 2.1 and 2.2), which were approximately 15 percent lower than theoretical, were obtained by interpolating pressures obtained by Project 1.1b. Times of rise of about 0.0025 seconds at a ground range of 6,625 feet and 0.0030 seconds at a ground range of 4,400 feet were observed.

Recorded front-wall pressures on the windowless structures (3.29 a and c) are shown in Figures 2.3 and 2.4. The times of rise on the reflected front-wall records are several times larger than indicated on the air-pressure records. Another departure from the expected results was the relatively large time interval between the recorded values of peak pressure and stagnation pressure (Figures 3.1 and 3.2). Pressure instrumentation was, unfortunately, not provided for the windowed structures (3.29b and d).

The recorded pressures for the roof of Structure 3.29c and the exterior of the rear walls of Structures 3.29a and c are shown in Figures 2.5, 2.6, and 2.7, respectively. Since many of the rear panels remained intact after failure of the corresponding front panels, pressure instrumentation on the interior face of the rear wall would have been of great value.

### 2.2 STRUCTURAL RESULTS

The test results, and as-built information for each of the panels and interior partitions of the 3.29 structures, including preshot photography, postshot photography, and selected motion picture frames which were taken during the test, are given on the following pages (Figures 2.9 through 2.221). Because of the large amount of dust and debris, the motion picture frames made during the test of the rear walls were of no value and are not included in this report.

The key plans and elevations of the 3.29 structures are shown in Figure 2.8. The values of maximum deflection for the instrumented panels are given in this section, and the full deflection records for the corresponding panels are shown in Figures 3.5 through 3.21. The term "fundamental frequency," as used in this report, refers to the lowest "natural frequency." As-built construction details for the curtain wall panels and interior partitions are shown in Figures 2.222 through 2.242.

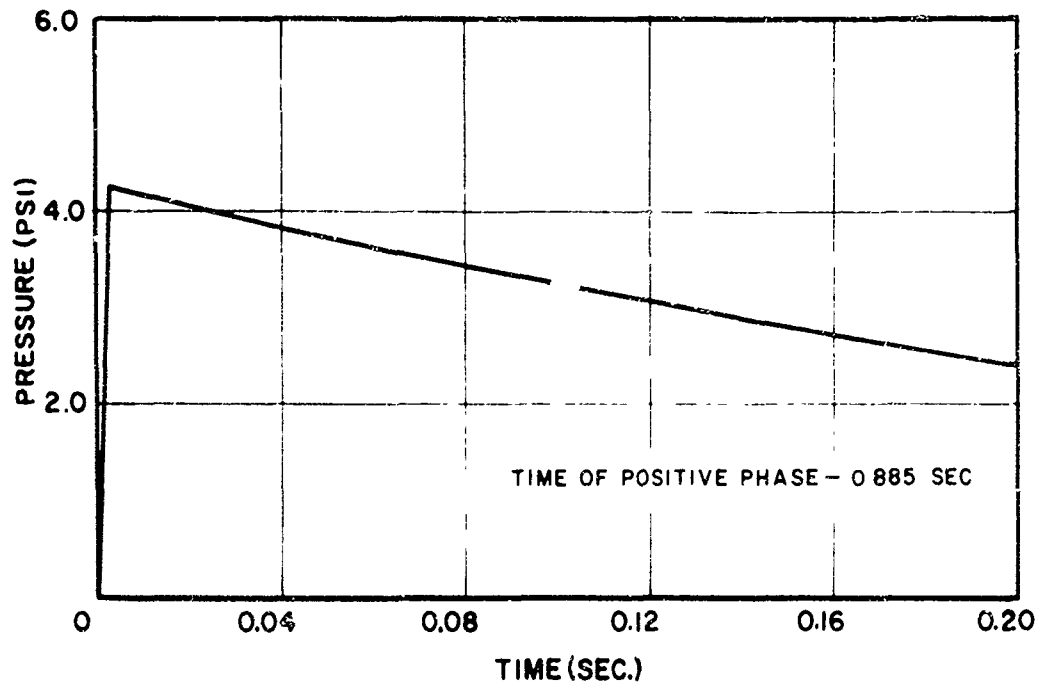


Figure 2.1 Air pressure, surface level, range 6,625 feet.

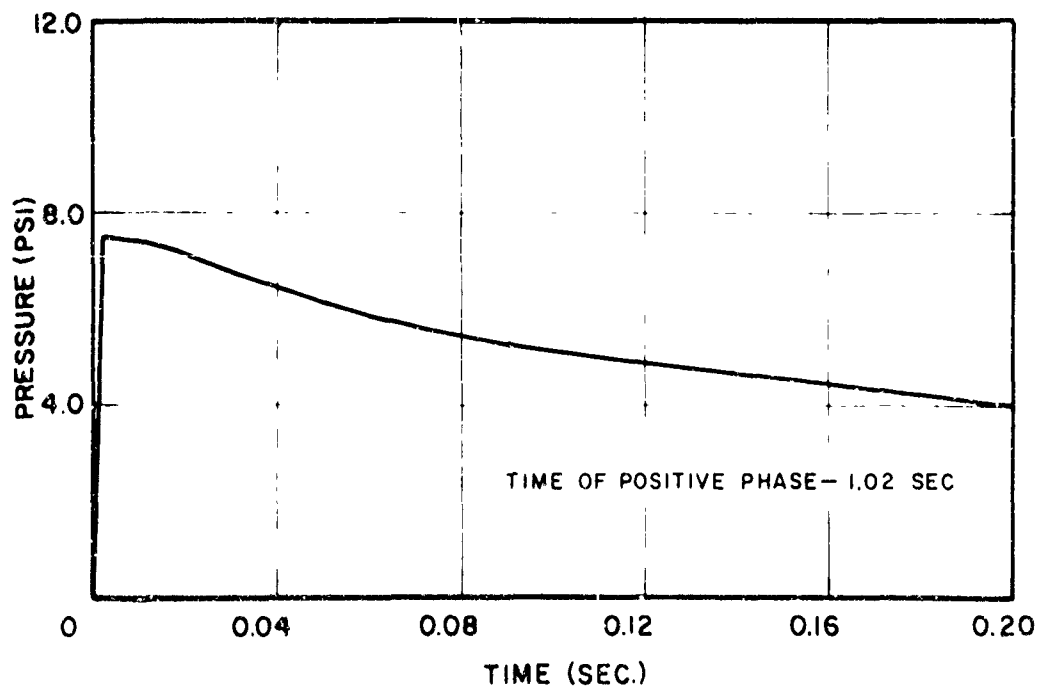


Figure 2.2 Air pressure, surface level, range 4,400 feet.

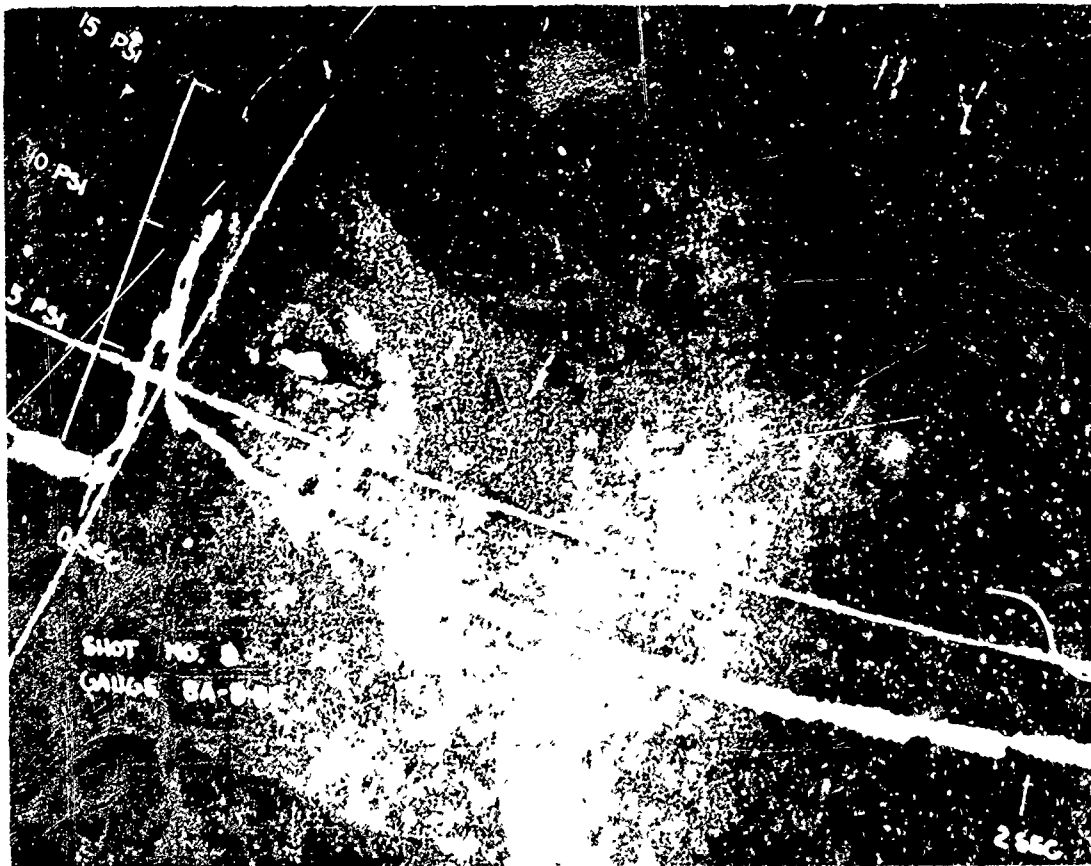


Figure 2.3 Pressure versus time, front, Building 3.29a.

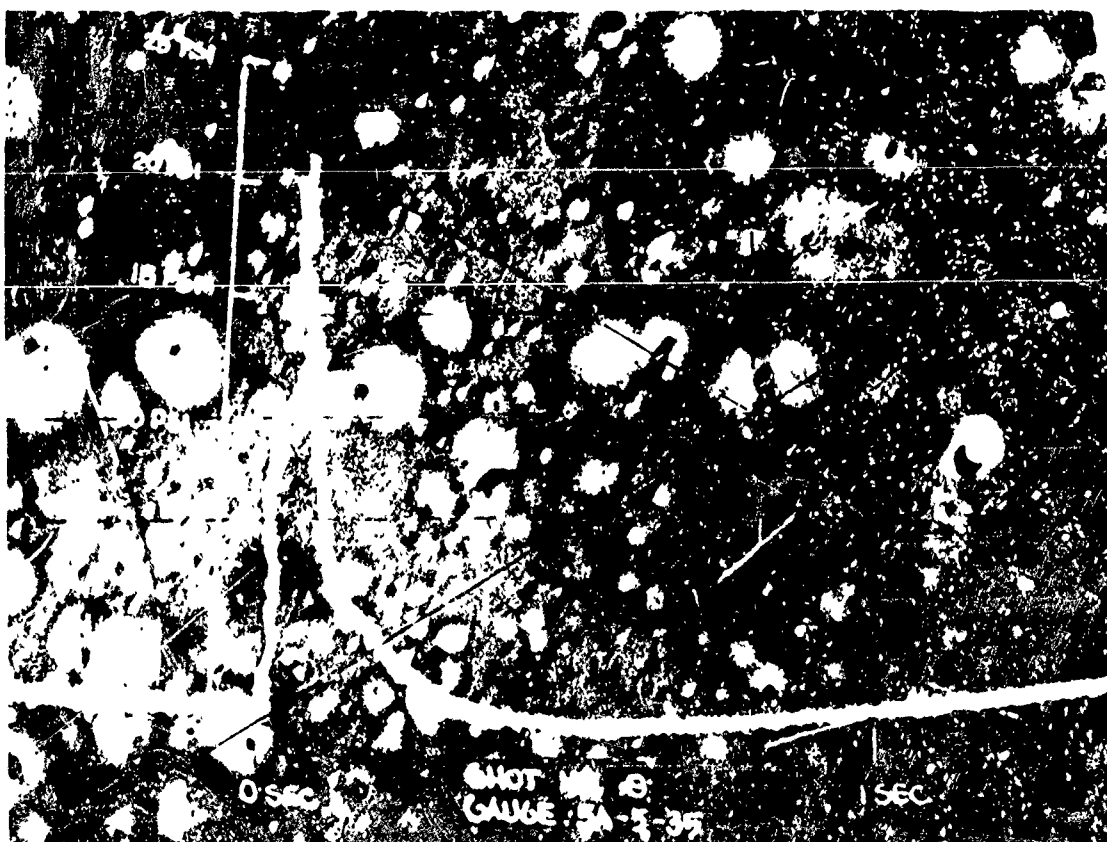


Figure 2.4 Pressure versus time, front, Building 3.29c





Figure 2.5 Pressure versus time, roof, Building 3.29c.

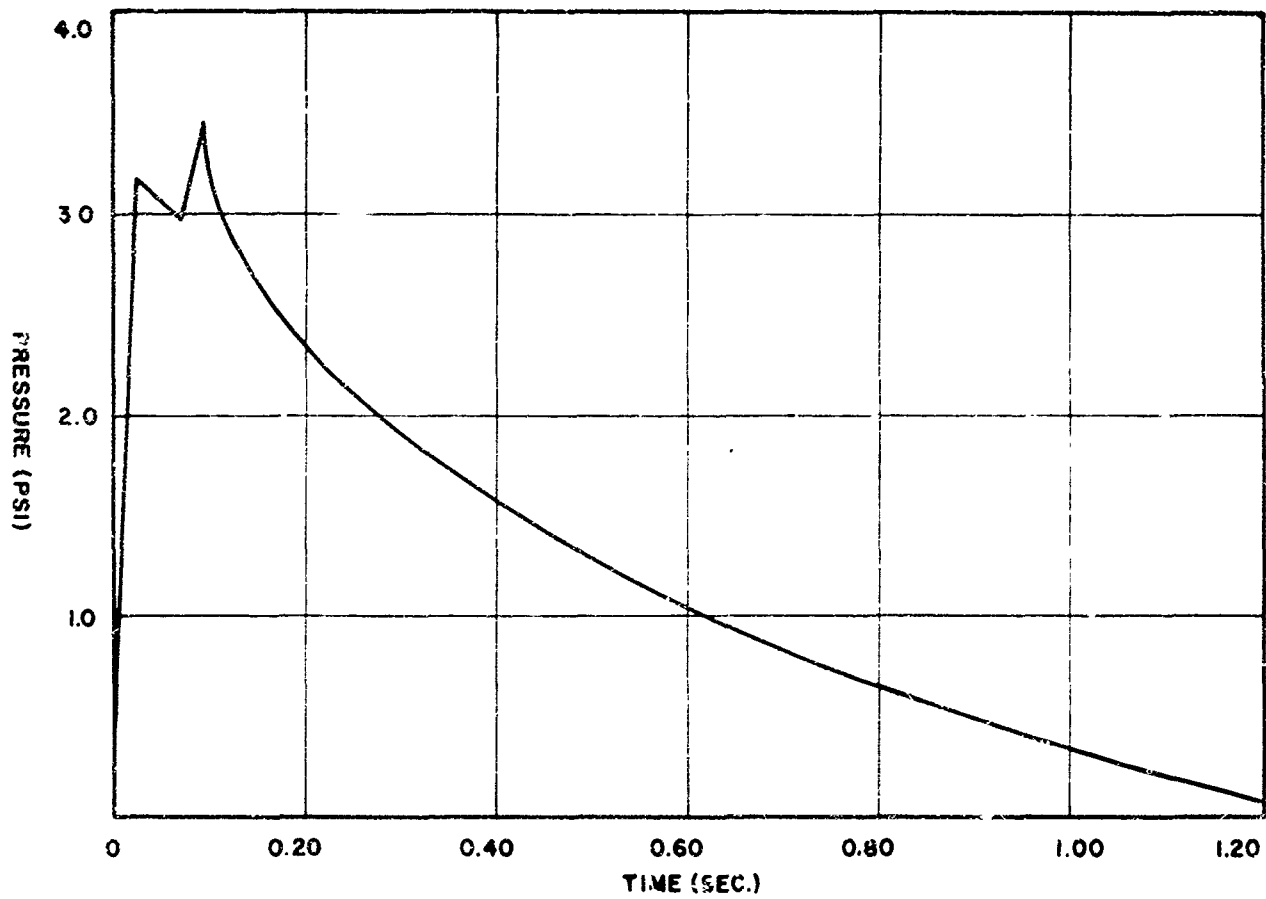


Figure 2.6 Rear wall pressure, Building 3.29a.

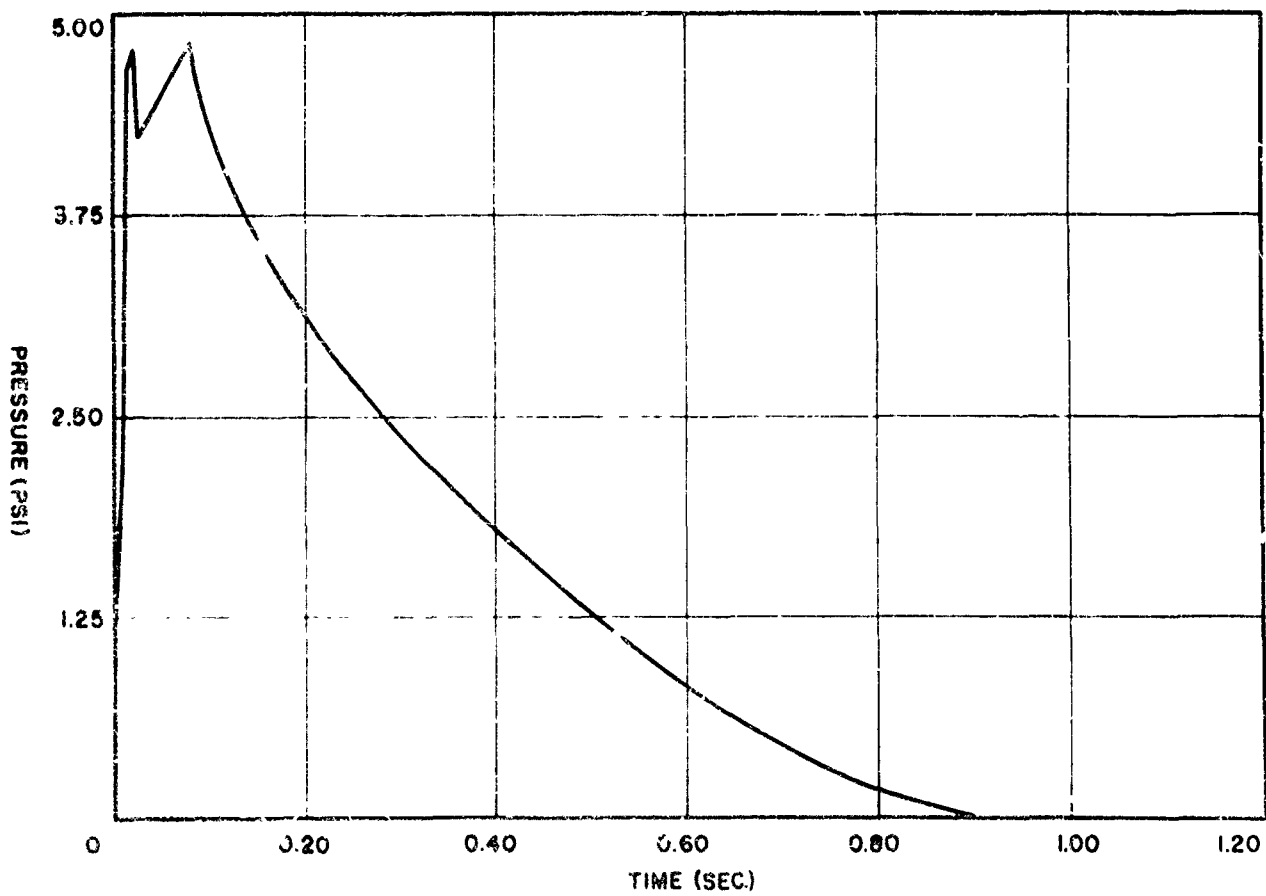
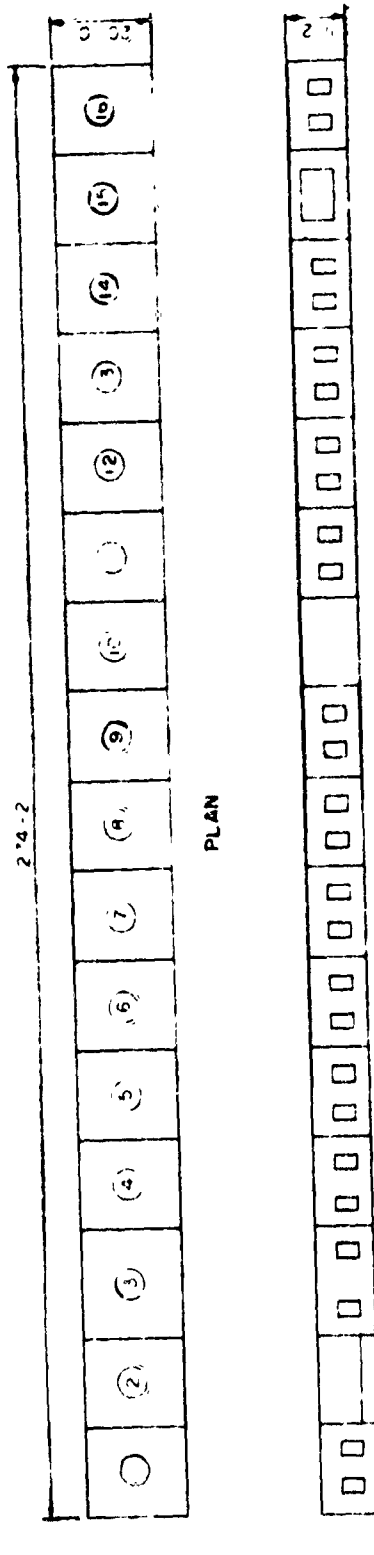
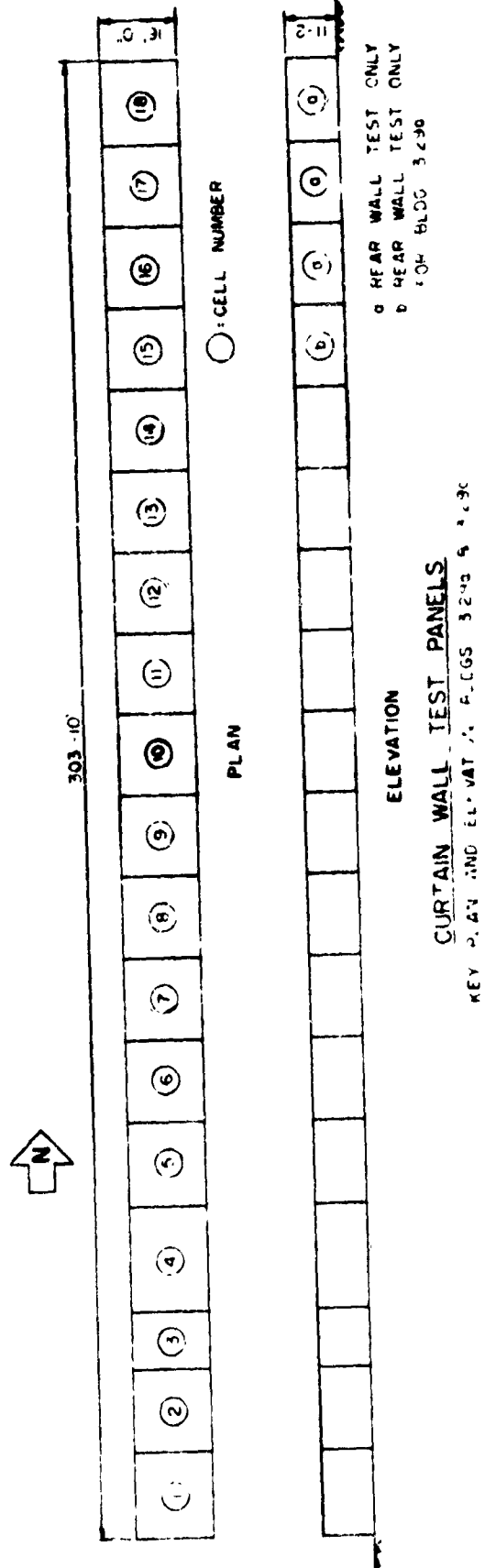
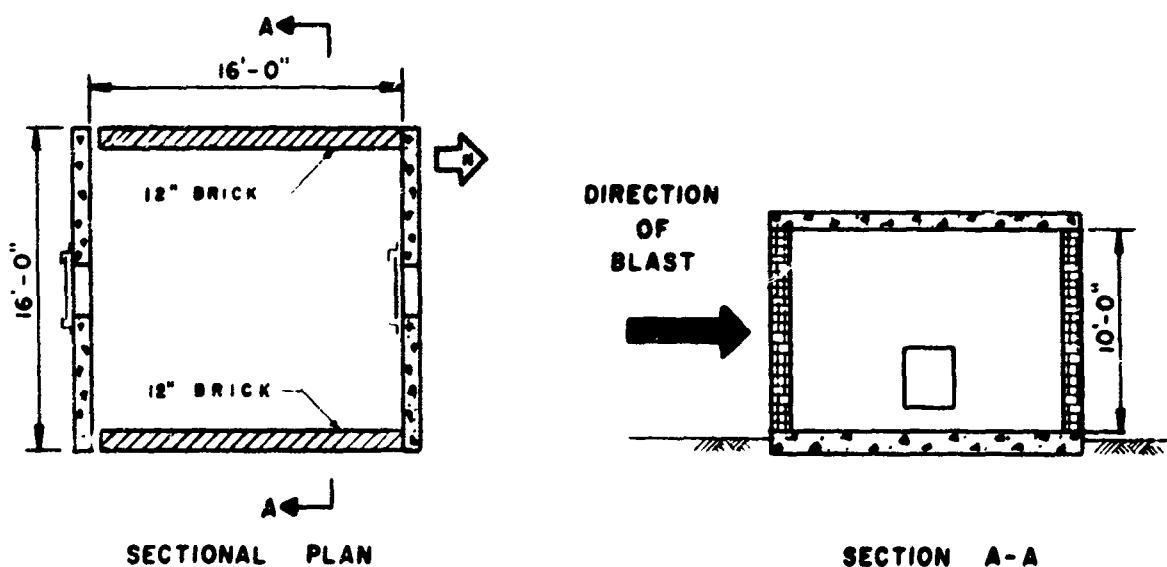


Figure 2.7 Rear wall pressure, Building 3.29c.



**Figure 2.8 Key plans and elevations, Buildings 3.29a, 3.29b, 3.29c and 3.29d.**

CELL NO. 16 10' x 16' OPENING



**DESCRIPTION.**

The front and rear walls consisted of 12 in. solid brick with headers placed every 7th course and mortar joints at the top and bottom. The south edge had an angle extending from the bottom of the roof slab to the top of the floor slab, for a fibre glass cloth blast closure of the joint. The north edge had dovetail anchors and a mortar joint.

**CONSTRUCTION ERRORS AND OMISSIONS:**

The angle at the south edge, holding the fibre glass cloth, should not have extended above the bottom of the roof slab or below the top of the floor slab.

**FIELD DAMAGE NOTES:**

There was no observable damage.

The maximum recorded displacement of the front wall was 0.47 in.

The measured, pre shot and post shot, natural frequencies of the front wall were 51.7 cps and 31.2 cps, respectively. For the rear wall, the measured, pre shot and post shot, natural frequencies were 56.0 cps and 41.3 cps, respectively.



Front Wall



Rear Wall

Fig. 2.9 Pre Shot Photography - Cell No. 1a



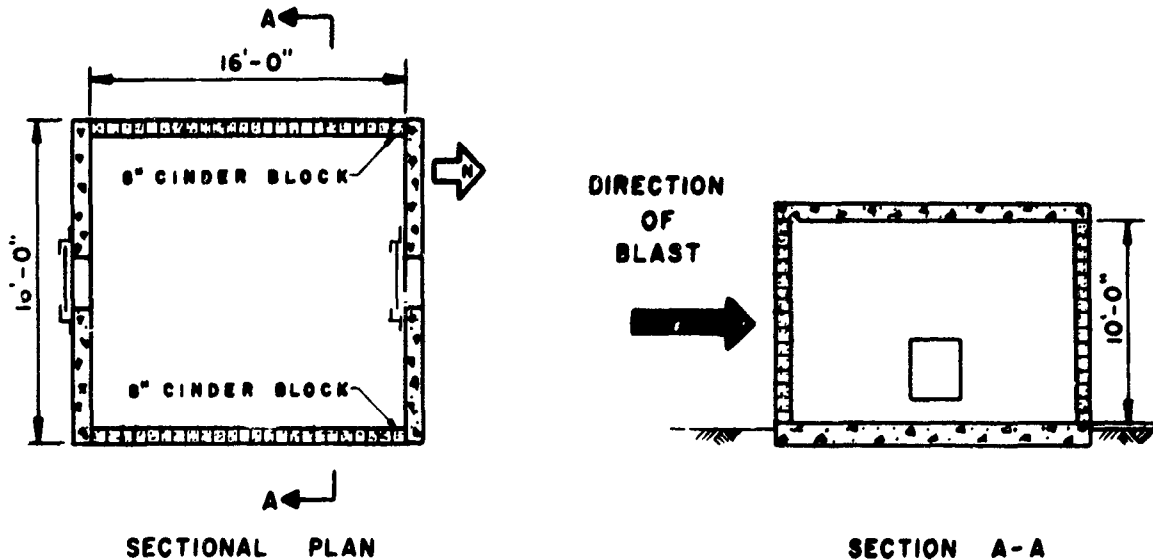
Front Wall



Rear Wall

Fig. 2.10 Post Shot Photography - Cell No. 1a

# CELL NO. 2a 10'x16' OPENING



## DESCRIPTION:

The front and rear walls consisted of 8 in. cinder block with mortar joints at the top and bottom and dovetail anchors and mortar joints at the side edges.

## CONSTRUCTION ERRORS AND OMISSIONS:

Square end, two cell blocks were used instead of the three cell type. A post test examination indicated that there was apparently little or no mortar bond at the floor and roof of the front wall.

## FIELD DAMAGE NOTES:

The front wall was blown into the cell with only edge material remaining in places.

The rear wall was bowed out 1-1/2 in. to 2 in. with a vertical crack running down the center of the outside face. There was some diagonal cracking and spalling at the top of the outside face. The inside face had diagonal cracks extending from the upper corner and one 2 in. diameter puncture of the inner wall of block. The wall appeared to be on the verge of failure.

The measured, pre shot frequency of the front wall was 33.4 cps. For the rear wall, the measured, pre shot and post shot, natural frequencies were 35.9 cps and 28.0 cps, respectively.



Front Wall

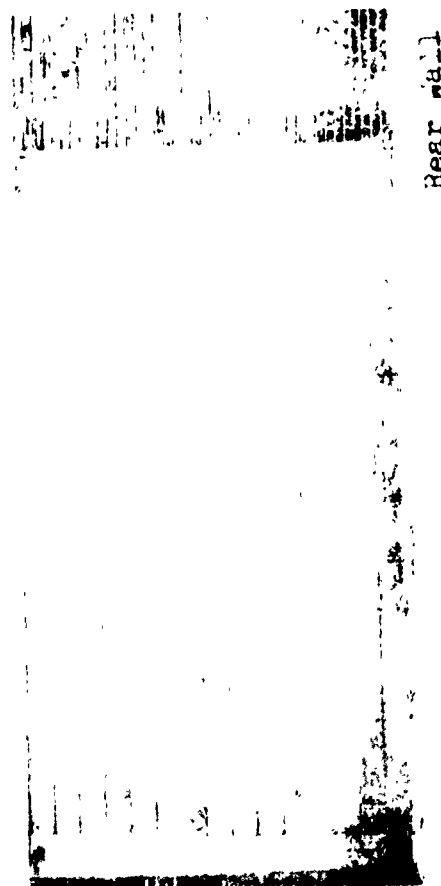


Rear Wall

Fig. 2.12 Post Shot Photography - Cell No. 2a



Front Wall



Rear Wall

Fig. 2.11 Pre Shot Photography - Cell No. 2a

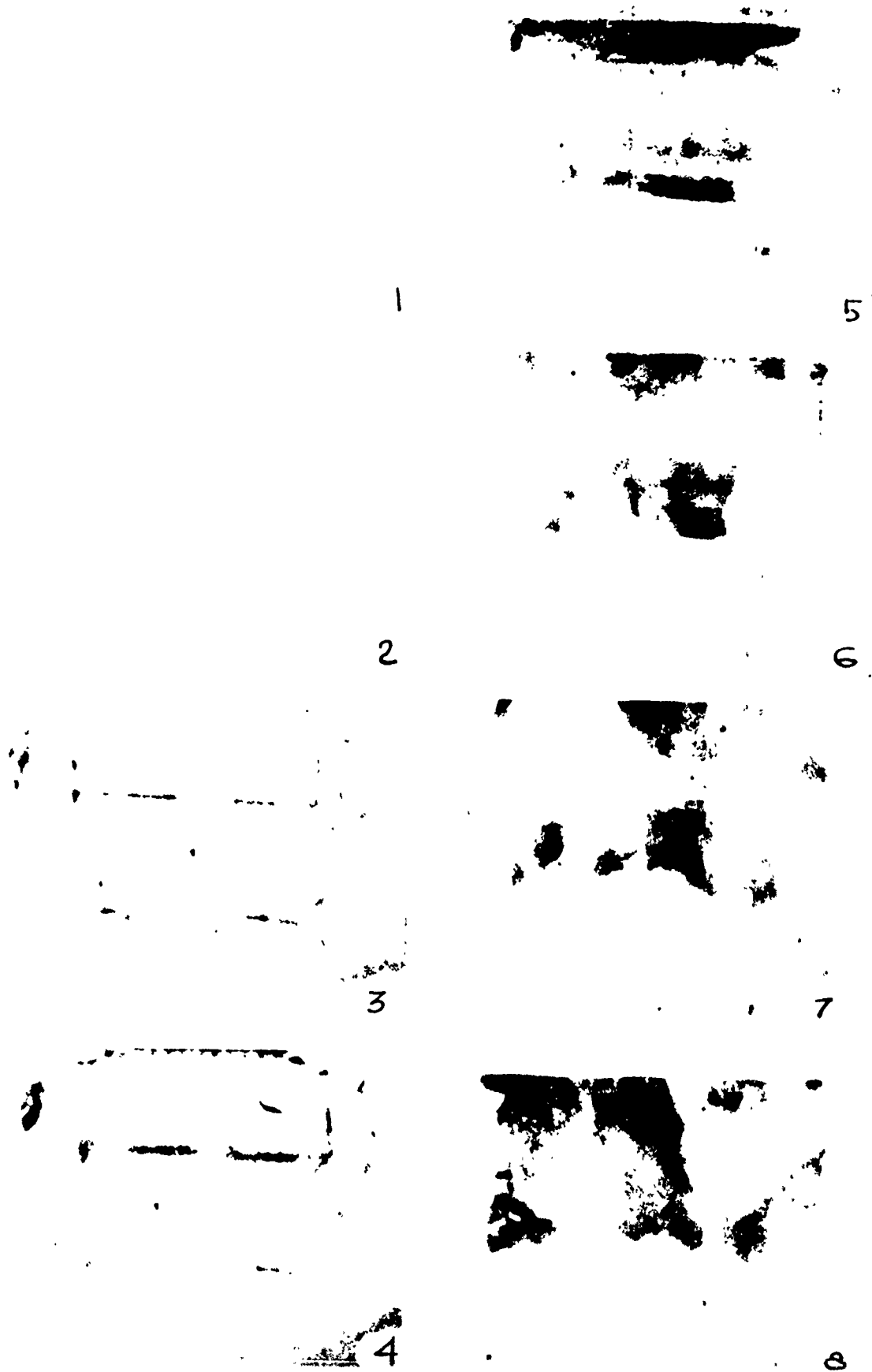
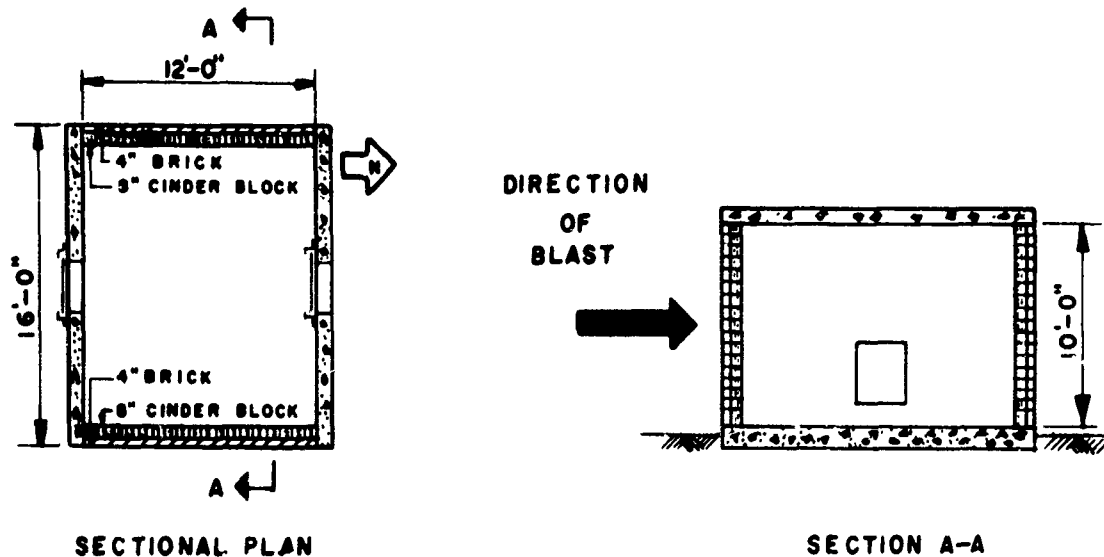


Fig. 2.13 Motion Picture Sequence - Front Wall - Cell No. 2a



# CELL NO. 3 a 10' x 12' OPENING



## DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing with 8 in. cinder block backing. Standard brick ties were placed every 6th course and at 4 ft on centers with mortar joints at the top and bottom and dovetail anchors and mortar joints at the side edges.

## CONSTRUCTION ERRORS AND OMISSIONS:

None

## FIELD DAMAGE NOTES:

The front wall was slightly spalled, at the top, on the outside face.

The rear wall was slightly spalled, at the top, on the outside face.

The measured, pre shot, natural frequency of the front wall was 42.6 cps. For the rear wall, the measured, pre shot and post shot, natural frequencies were 44.0 cps and 29.8 cps, respectively.



Front Wall



Front Wall

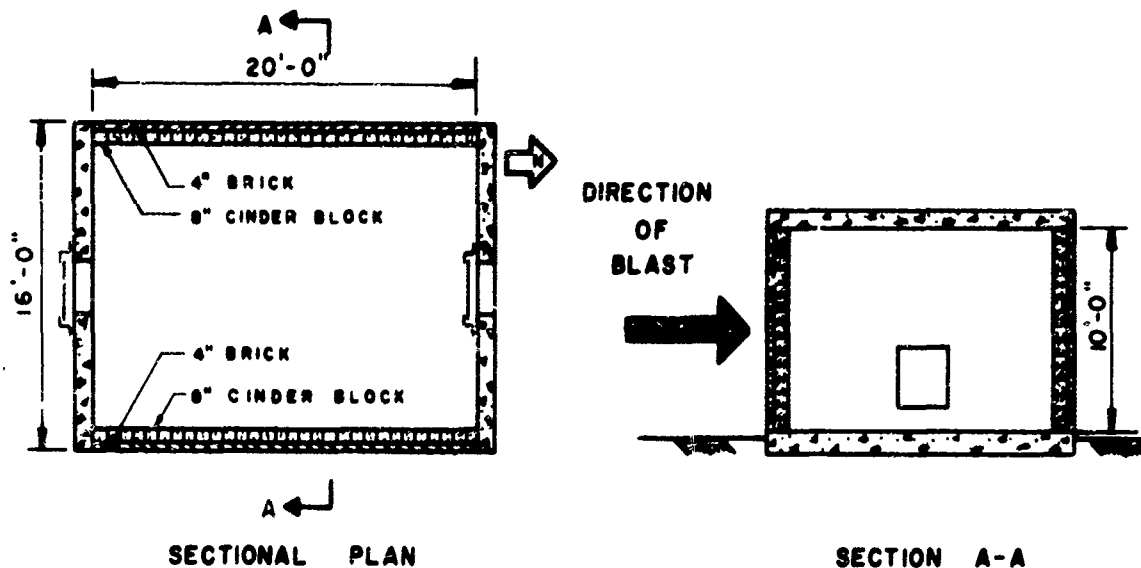


Fig. 2.14 Post Shot Photography - Cell No. 3a



Fig. 2.15 Post Shot Photography - Cell No. 3a

# CELL NO. 4 a 10'x20' OPENING



## DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing with 8 in. cinder block backing. Standard brick ties were placed every 6th course and at 4 ft on centers with mortar joints at the top and bottom and dovetail anchors and mortar joints at the side edges.

## CONSTRUCTION ERRORS AND OMISSIONS:

None

## FIELD DAMAGE NOTES:

The front wall was displaced inward at the top  $1/4$  in. to  $3/4$  in. It is probable that all or part of this displacement was present prior to the shot. The outside face was spalled in two small spots in the center of the panel. The inside face had a slight horizontal crack at the mortar joint halfway up for the center  $2/3$  of the wall.

The rear wall was slightly spalled, at the top, on the outside face.

The measured, pre shot and post shot, natural frequencies of the front wall were 35.1 cps and 18.8 cps, respectively. For the rear wall, the measured, pre shot and post shot, natural frequencies were 33.0 cps and 23.0 cps, respectively.



Front wall

Front wall



Rear wall

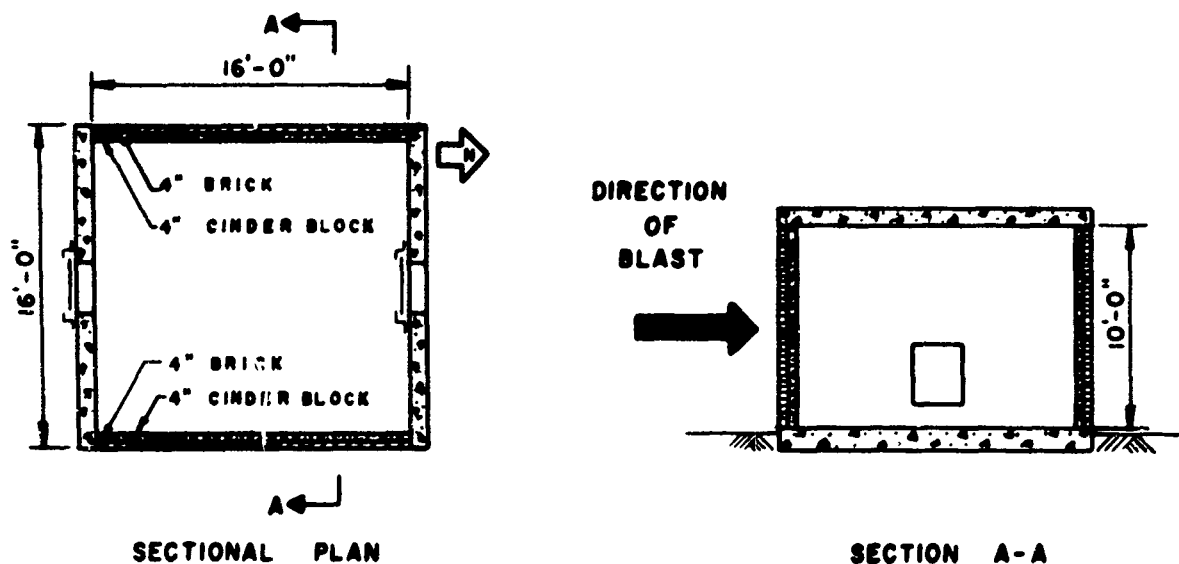


Rear wall

Fig. 2.16 Pre Shot Photography - Cell No. 4a

Fig. 2.17 Post Shot Photography - Cell No. 4a

# CELL NO. 5a 10'x16' OPENING



## DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing with 4 in. cinder block backing. Standard brick ties were placed every 6th course and at 4 ft on centers with mortar joints at the top and bottom with an angle bearing on the inside. The side edges had dovetail anchors and mortar joints.

## CONSTRUCTION ERRORS AND OMISSIONS:

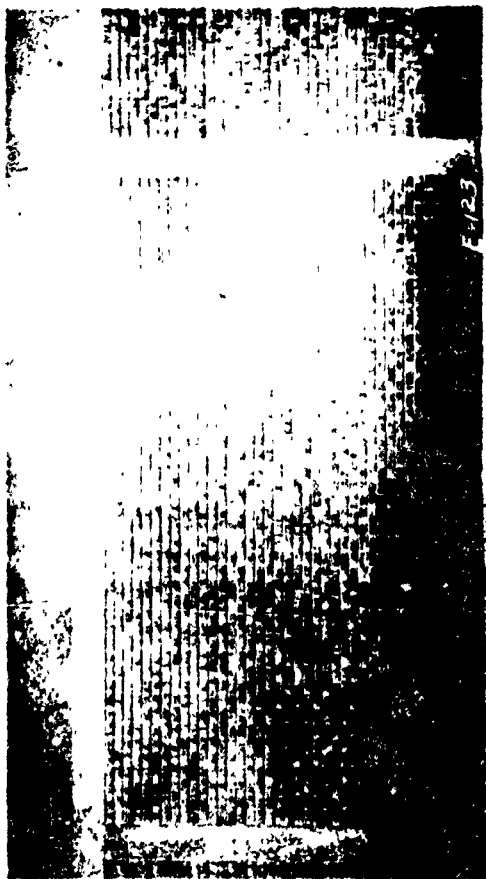
None

## FIELD DAMAGE NOTES:

The front wall was 85 percent blown into the cell (oval pattern) with 4 courses at the top and 3 courses at the bottom remaining.

The rear wall had a slight vertical crack on the inside face, for center 2/3 of height with evidence of debris striking the wall at the same location.

The measured, pre shot, natural frequency of the front wall was 32.2 cps. For the rear wall, the measured, pre shot and post shot, natural frequencies were 30.2 cps and 18.9 cps, respectively.



Front Wall



Rear Wall

Fig. 2.18 Pre Shot Photography - Cell No. 5a



Front Wall



Rear Wall

Fig. 2.19 Post Shot Photography - Cell No. 5a

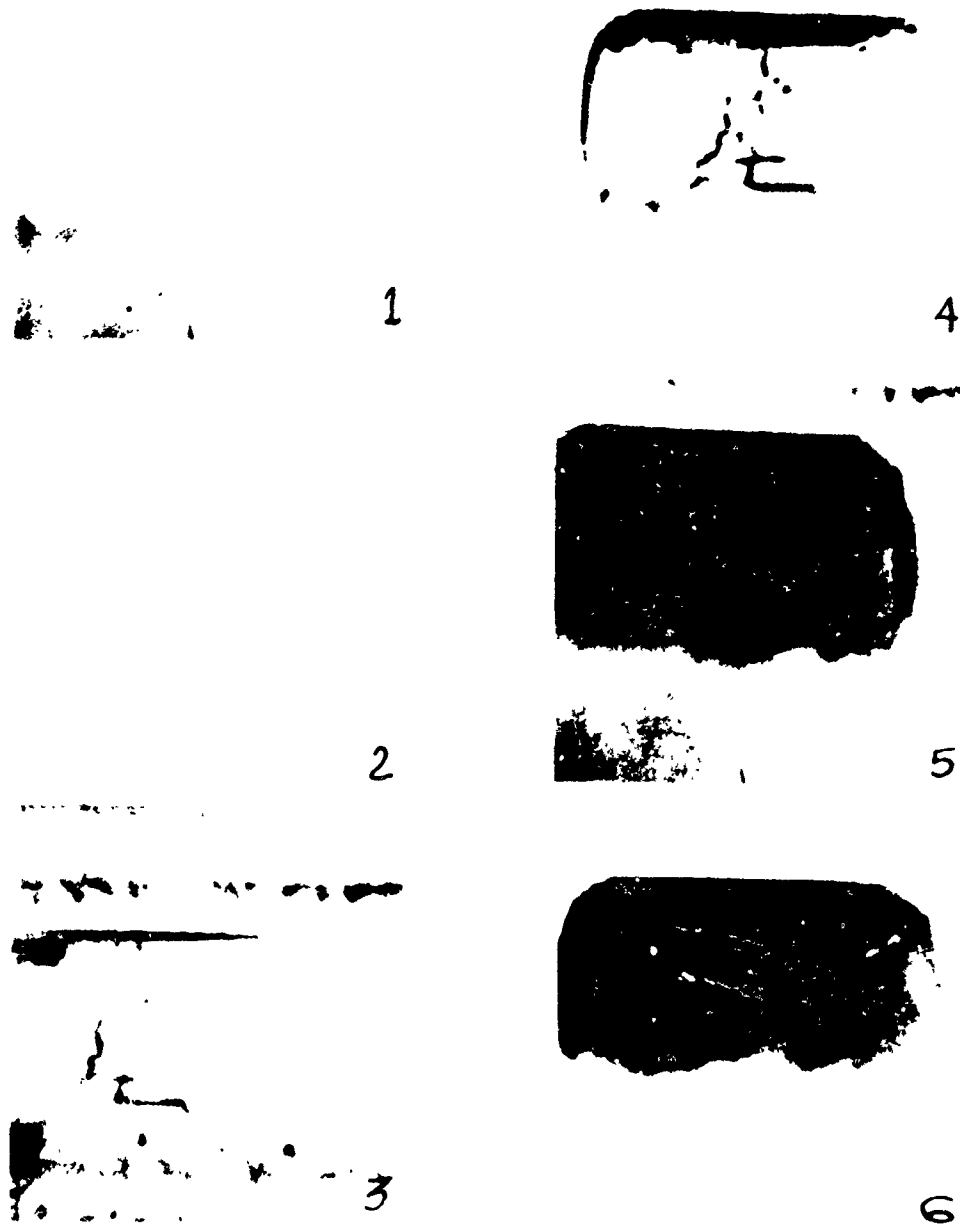
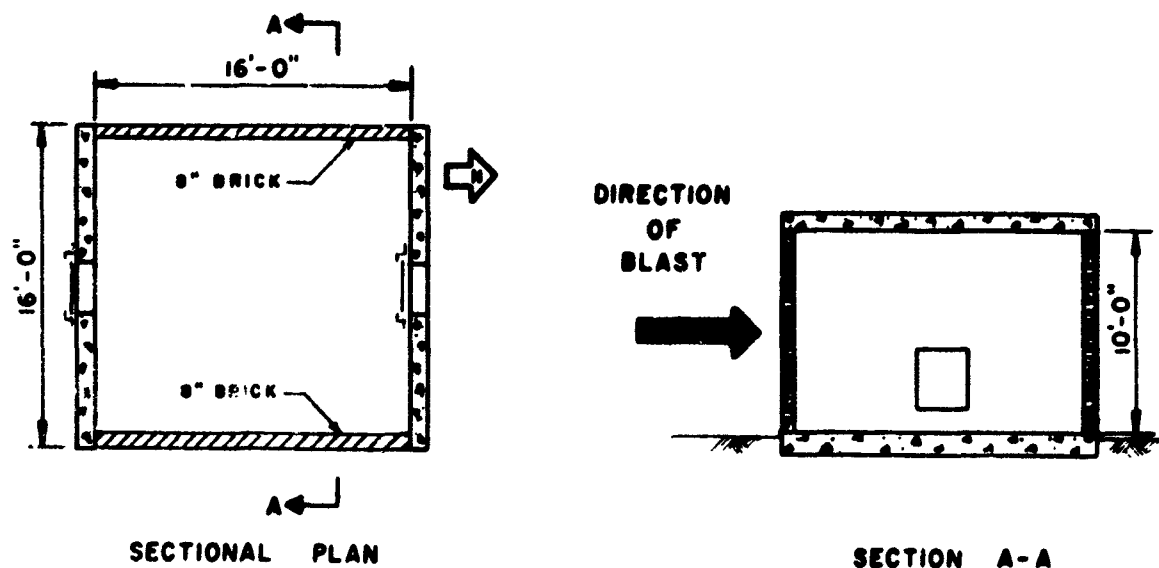


Fig. 2.20 Motion Picture Sequence - Front Wall - Cell No. 5a

# CELL NO. 60 10'x16' OPENING



## DESCRIPTION.

The front and rear walls consisted of 8 in. solid brick with headers placed every 7th course and mortar-joints at the top and bottom. The side edges had dovetail anchors and mortar joints.

## CONSTRUCTION ERRORS AND OMISSIONS:

None

## FIELD DAMAGE NOTES:

The front wall had 2 small spalled spots in the center of the outside face. The inner wythe, on the inside face, between the headers was knocked inward  $3/8$  in. maximum, at the center of the panel (4 courses of brick 3'-0" long).

The measured, pre shot and post shot, natural frequencies of the front wall were 36.4 cps and 20.0 cps, respectively. For the rear wall, the measured, pre shot and post shot, natural frequencies were 34.7 cps and 34.9 cps, respectively.





Fig. 2.22 Post Shot Photography - Cell No. 6a

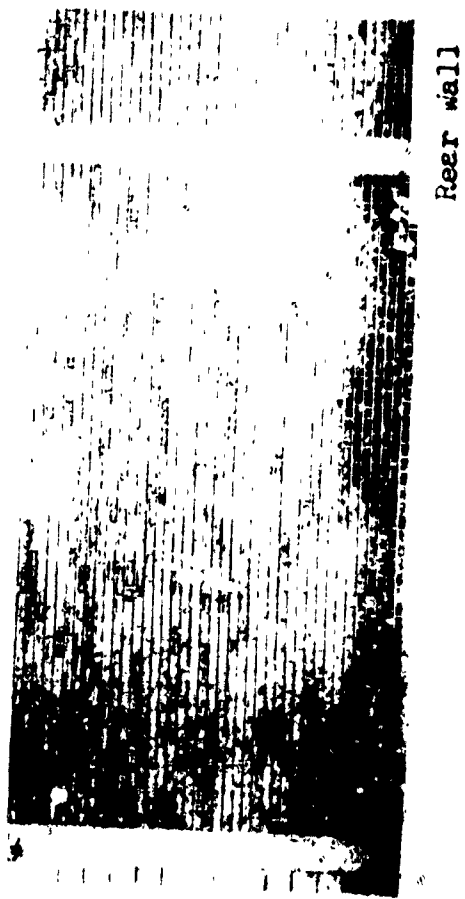
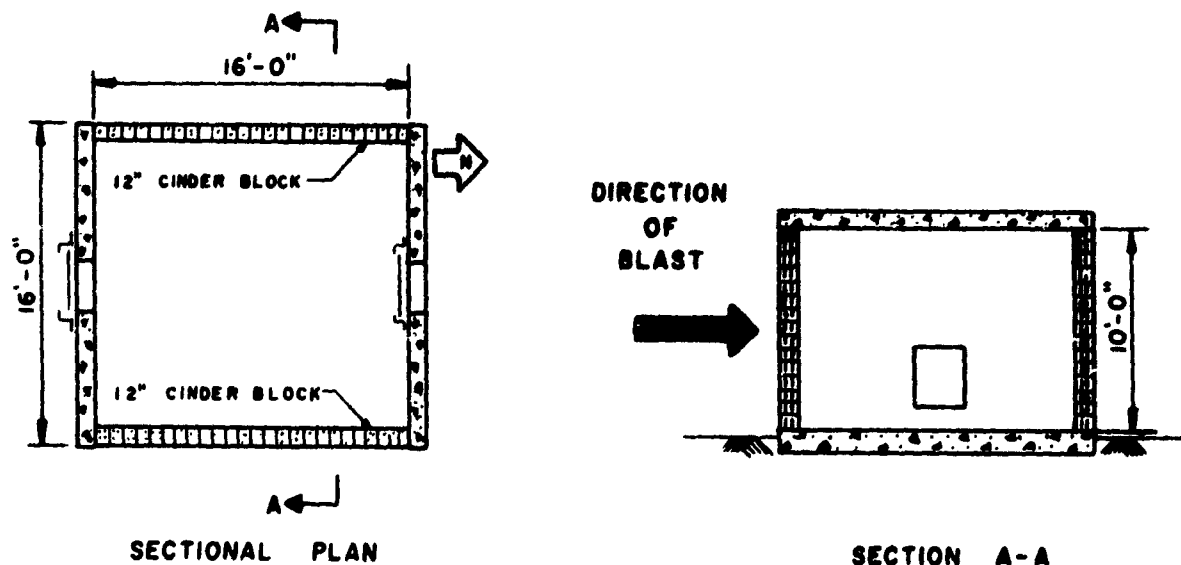


Fig. 2.21 Pre Shot Photography - Cell No. 6a

# CELL NO. 7a 10'x16' OPENING



## DESCRIPTION:

The front and rear walls consisted of 12 in. cinder block with mortar joints at the top and bottom. The side edges had dovetail anchors and mortar joints.

## CONSTRUCTION ERRORS AND OMISSIONS:

None

## FIELD DAMAGE NOTES:

The front wall was 80 percent blown into the cell.

The rear wall was slightly spalled, at the top, on the outside face.

The measured, pre shot, natural frequency of the front wall was 38.3 cps. For the rear wall, the measured, pre shot and post shot, natural frequencies were 48.4 cps and 44.2 cps, respectively.



Front Wall

Rear Wall

Fig. 2.23 Pre Shot Photography - Cell No. 7a



Rear Wall

Fig. 2.24 Post Shot Photography - Cell No. 7a

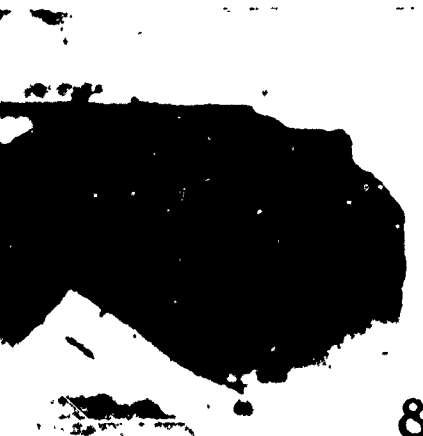
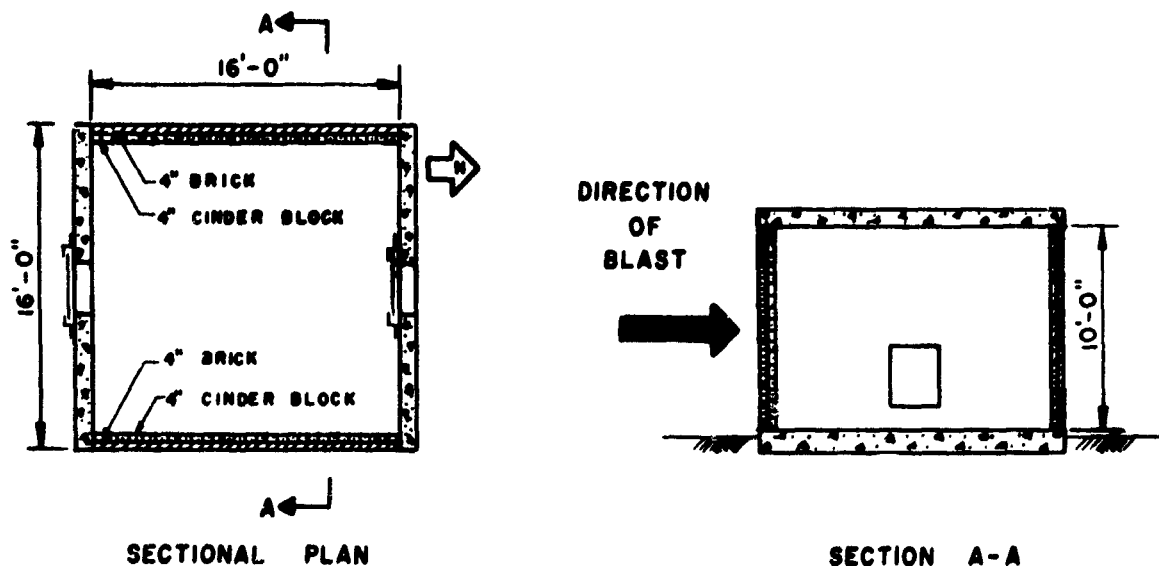


Fig. 2.25 Motion Picture Sequence - Front Wall - Cell No. 7a

# CELL NO. 8 a 10'x16' OPENING



## DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing with 4 in. cinder block backing. Standard brick ties were placed every 6th course and at 4 ft on centers with mortar joints at the top and bottom and dovetail anchors and mortar joints at the side edges.

## CONSTRUCTION ERRORS AND OMISSIONS:

None

## FIELD DAMAGE NOTES:

The front wall was 70 percent blown into the cell with debris evenly distributed.

The measured, pre shot, natural frequency of the front wall was 26.7 cps. For the rear wall, the measured, pre shot and post shot, natural frequencies were 30.3 cps and 25.9 cps respectively.



Front Wall



Rear Wall

Fig. 2.27 Post Shot Photography - Cell No. 8a



Front Wall



Rear Wall

Fig. 2.26 Pre Shot Photography - Cell No. 8a

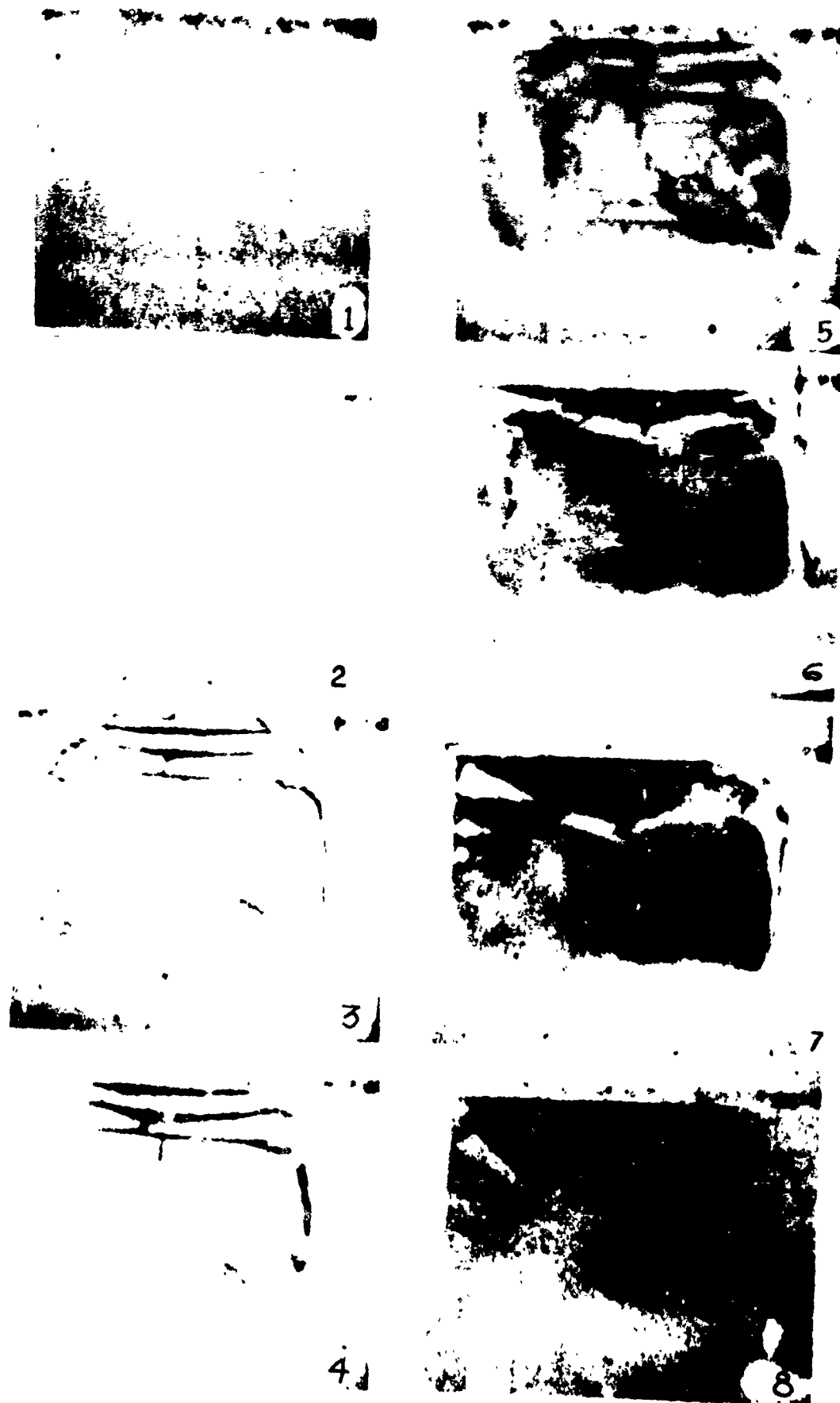
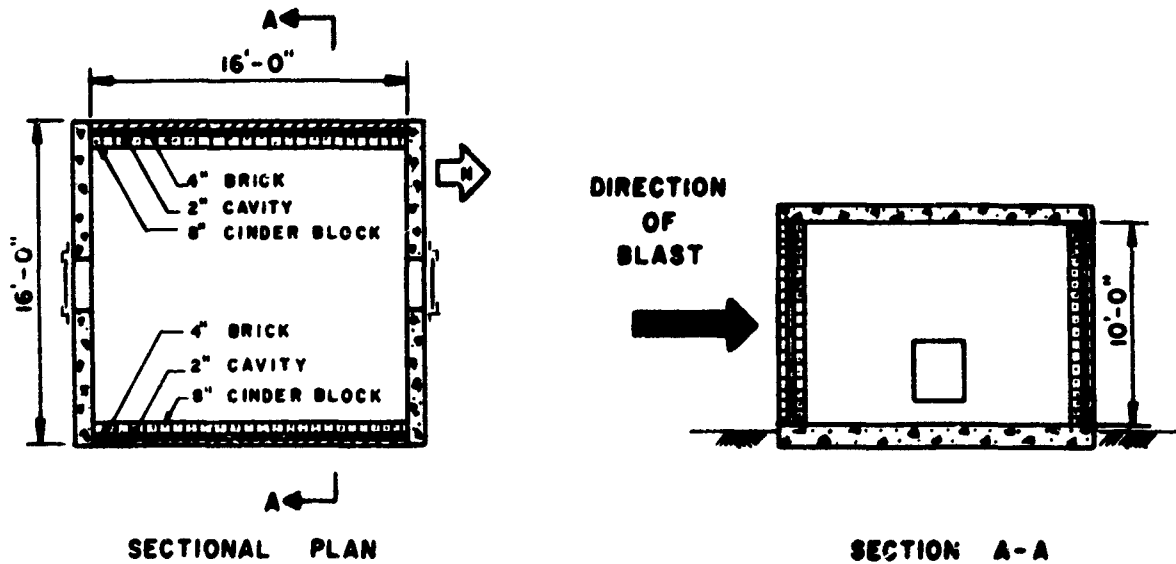


Fig. 2.28 Motion Picture Sequence - Front Wall - Cell No. 8a

## CELL NO. 9 a 10'x16' OPENING



### DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing, 2 in. cavity, and 8 in. cinder block backing. Z shaped brick ties were placed every 6th course and at 1/4 ft on centers with mortar joints at the top and bottom and dovetail anchors and mortar joints at the side edges.

### CONSTRUCTION ERRORS AND OMISSIONS:

None

### FIELD DAMAGE NOTES:

The front wall was 65 percent blown into the cell.

The rear wall had a vertical crack on the inside face from the top, down 2/3 of the wall, at about the center.

The measured, pre shot, natural frequency of the front wall was 18.7 cps. For the rear wall, the measured, pre shot and post shot, natural frequencies were 25.6 cps and 10.9 cps, respectively.



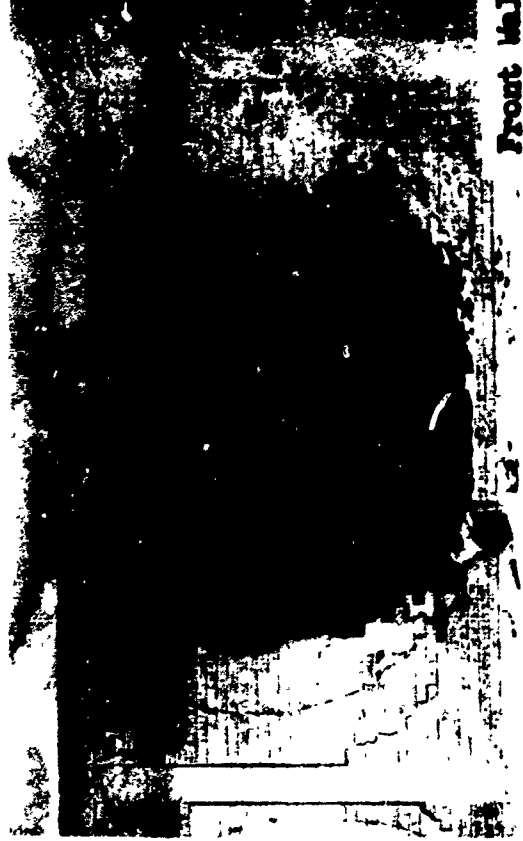


Fig. 2.29 Pre Shot Photography - Cell No. 9a

Fig. 2.30 Post Shot Photography - Cell No. 9a



1



5



6



2



3



7



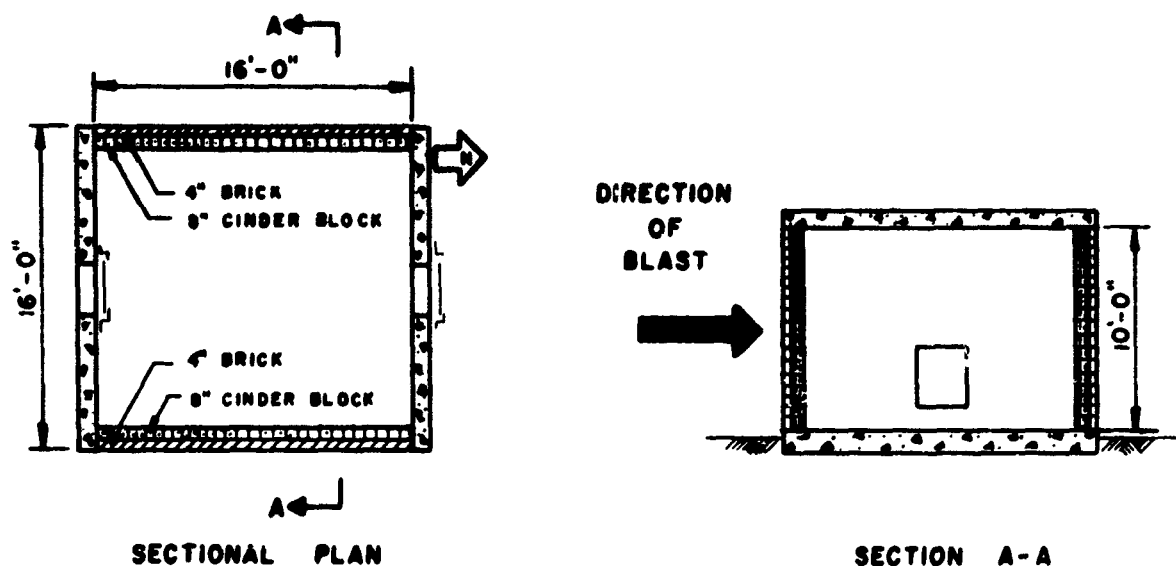
4



8

Fig. 2.31 Motion Picture Sequence - Front Wall - Cell No. 9a

# CELL NO. 10 a 10' x 16' OPENING



## DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing with 8 in. cinder block backing. Standard brick ties were placed every 6th course and at 4 ft on centers with mortar joints at the top and bottom and an angle bearing on the inside. The side edges had dovetail anchors and mortar joints.

## CONSTRUCTION ERRORS AND OMISSIONS

None

## FIELD DAMAGE NOTES:

The front wall was slightly spalled, at the top, on the outside face with some vertical flexure cracking. There was a slight flexure opening of several horizontal mortar joints around the center of the inside face.

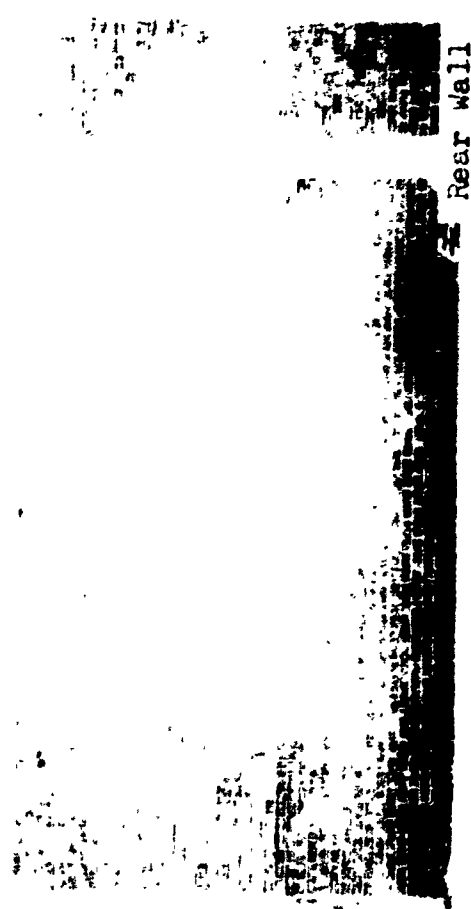
The rear wall was spalled slightly, at the top, on the outside face.

The maximum recorded displacements of the front and rear walls were 1.49 in. and 0.15 in., respectively.

The measured, pre shot and post shot, natural frequencies of the front wall were 47.5 cps and 19.1 cps, respectively. For the rear wall, the measured, pre shot and post shot, natural frequencies were 42.5 cps and 25.3 cps, respectively.

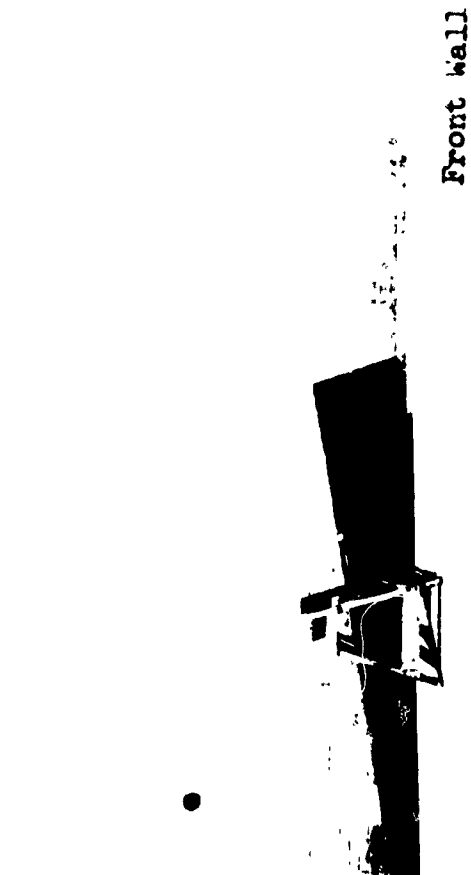


Front wall



Rear wall

Fig. 2.33 Post Shot Photography - Cell No. 10a



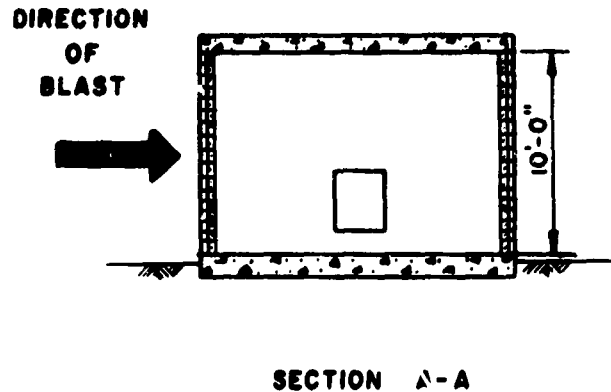
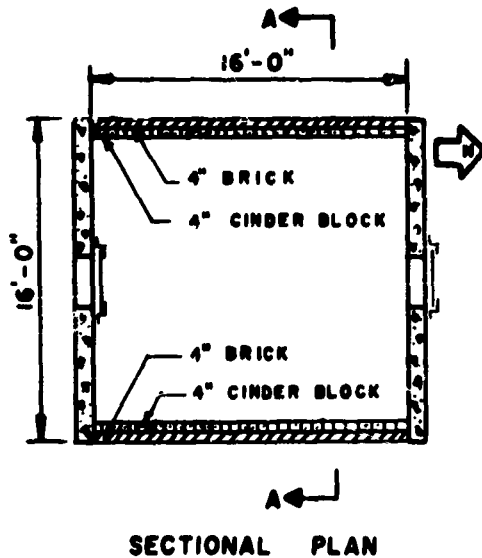
Front wall



Rear wall

Fig. 2.32 Pre Shot Photography - Cell No. 10a

# CELL NO. 11a 10'x16' OPENING



## DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing with 4 in. cinder block backing. Standard brick ties were placed every 6th course and at 4 ft on centers with joints at the top and bottom and dovetail anchors and mortar joints at the side edges.

## CONSTRUCTION ERRORS AND OMISSIONS:

There were poorly filled joints between brick and block in the front wall. The bond between the front wall and the floor slab was poor.

## FIELD DAMAGE NOTES:

The front wall was 95 percent blown into cell.

The rear wall was spalled on the outside face at the top, for the center  $3/4$  of the wall. There was a small outward movement at the center with a vertical crack extending from the top, down 5 courses, just to the right of center on the inside face.

The maximum recorded inward and outward displacements of the rear wall were 0.42 in. and 0.73 in., respectively.

The measured, pre shot, natural frequency of the front wall was 21.6 cps. For the rear wall, the measured, pre shot and post shot, natural frequencies were 28.0 cps and 20.3 cps, respectively.



Front Wall



Rear Wall

Fig. 2.35 Post Shot Photography - Cell No. 11a



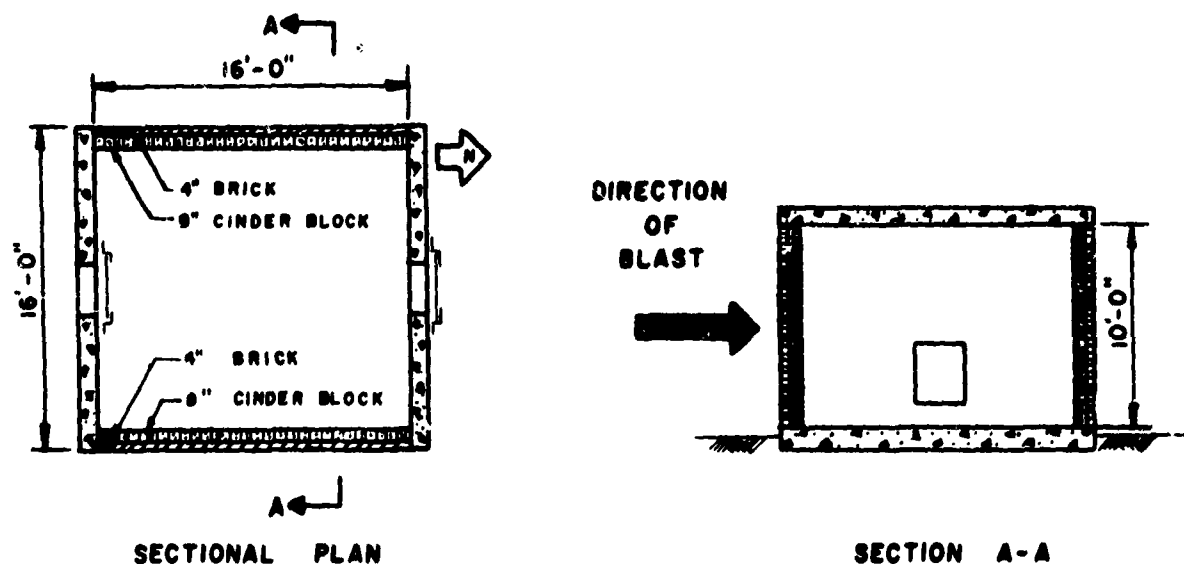
Front Wall



Rear Wall

Fig. 2.34 Pre Shot Photography - Cell No. 11a

# CELL NO. 12 a 10' x 16' OPENING



## DESCRIPTION.

The front and rear walls consisted of 4 in. brick facing with 8 in. cinder block backing. Standard brick ties were placed every 6th course and at 4 ft on centers. The bottom had a mortar joint and an angle for bearing on the inside. The top had a 3/4 in. open joint and an angle for bearing on the inside. The side edges had dovetail anchors and mortar joints.

## CONSTRUCTION ERRORS AND OMISSIONS:

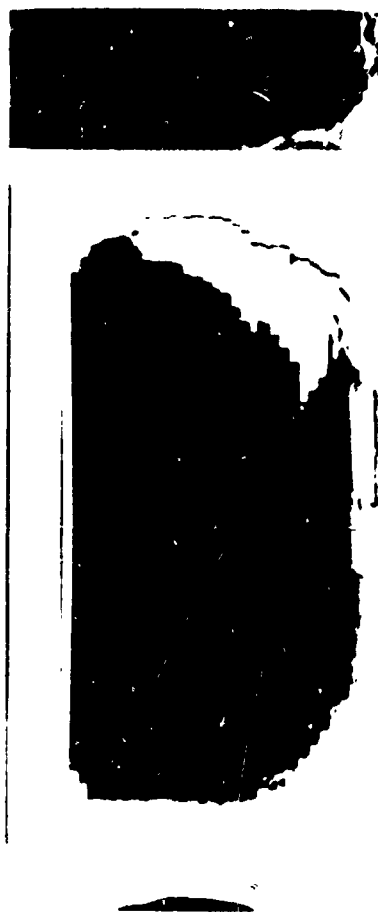
There was dubious bond between the brick and the block and apparently few brick ties were placed in the wall.

## FIELD DAMAGE NOTES:

The front wall was 75 percent blown in to the cell with 6 courses hanging at the top, and 3 courses at bottom remaining.

The maximum recorded inward and outward displacements of the rear wall were 0.29 in. and 0.24 in., respectively.

The measured, pre shot, natural frequency of the front wall was 17.2 cps. For the rear wall, the measured, pre shot and post shot, natural frequencies were 19.5 cps and 10.8 cps, respectively.

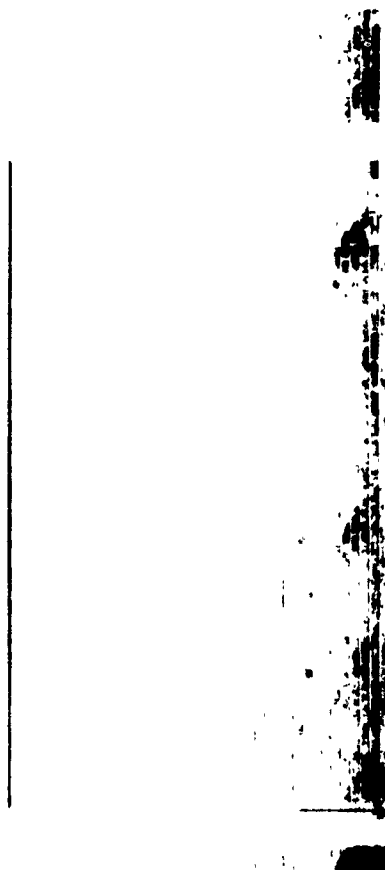


Front Wall

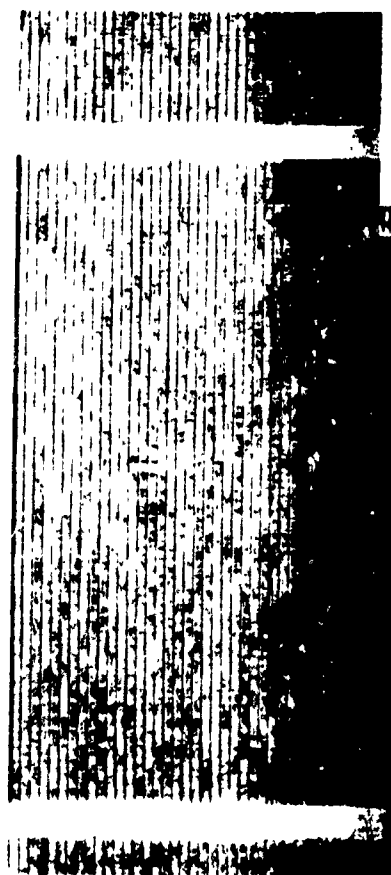


Rear Wall

Fig. 2.37 Post Shot Photography - Cell No. 12a



Front Wall

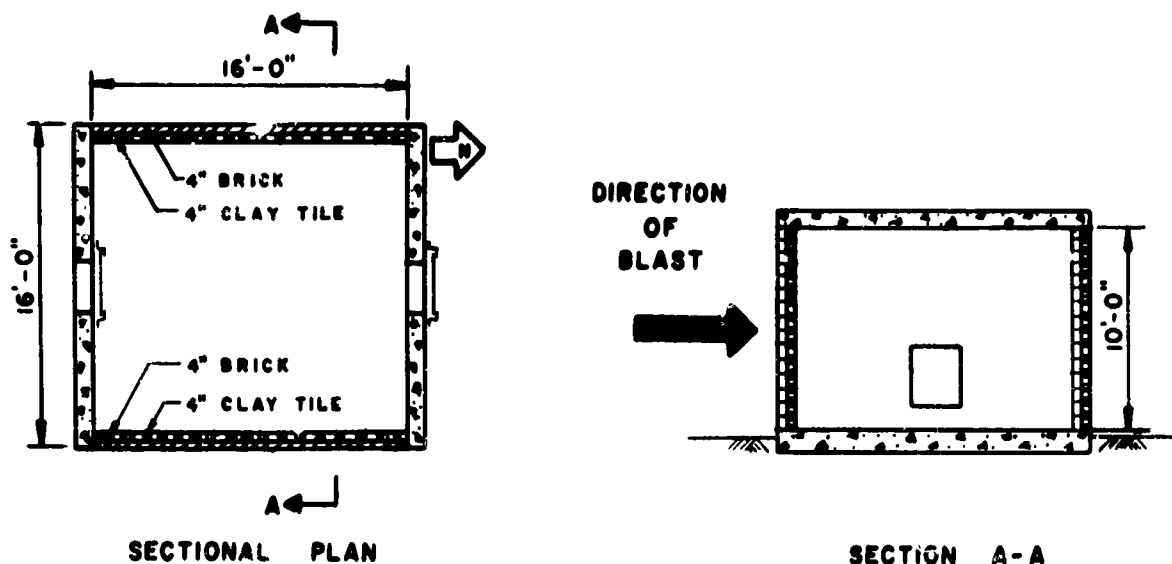


Rear Wall

Fig. 2.36 Pre Shot Photography - Cell No. 12a



# CELL NO. 13 a 10'x16' OPENING



## DESCRIPTION.

The front and rear walls consisted of 4 in. brick facing with 4 in. clay tile backing. Standard brick ties were placed at all tile joints except at the top and bottom. There were mortar joints at the top and bottom and dovetail anchors and mortar joints at the side edges.

## CONSTRUCTION ERRORS AND OMISSIONS:

None

## FIELD DAMAGE NOTES:

The front wall was 98 percent blown into the cell with the bottom corners remaining. Many tiles remained whole.

The rear wall was spalled (not severely) along the top on the outside face. The inside face had several small punctures, the size of a quarter in the tile wall.

The measured, pre shot, natural frequency of the front wall was 35.6 cps. For the rear wall, the measured, pre shot and post shot, natural frequencies were 36.1 cps and 13.6 cps, respectively.



Fig. 2.38 Pre Shot Photography - Cell No. 13a

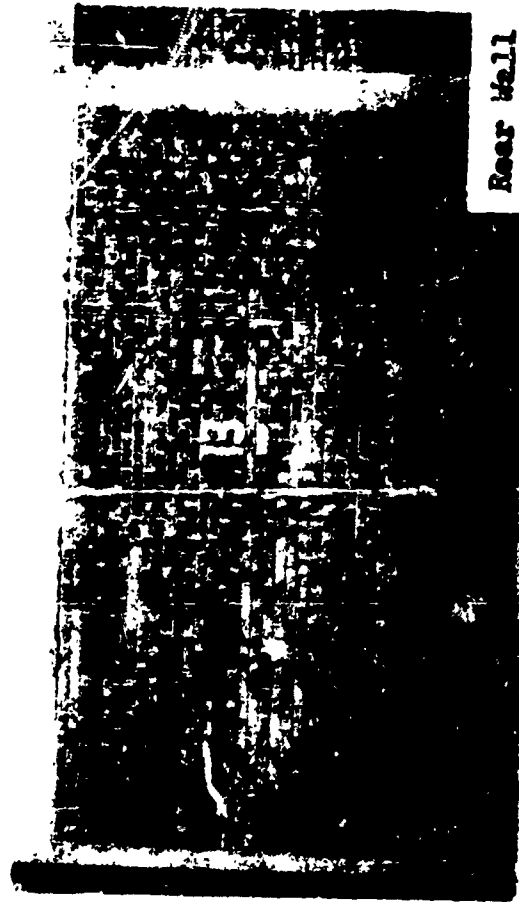


Fig. 2.39 Post Shot Photography - Cell No. 13a



1



2



3



4



5



6



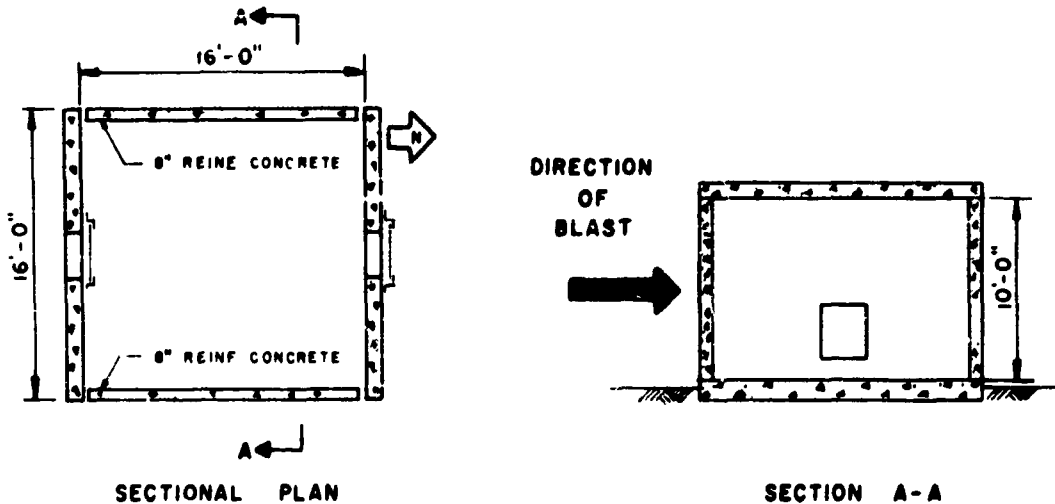
7



8

Fig. 2.40 Motion Picture Sequence - Front Wall - Cell No. 13a

# CELL NO. 14 a 10'x16' OPENING



## DESCRIPTION

The front and rear walls consisted of 8 in. reinforced concrete with keyed joints at the top and bottom. Each of the side edges had an angle extending from the top of the roof slab to the bottom of the floor slab for a fibre glass cloth blast closure of the joints.

## CONSTRUCTION ERRORS AND OMISSIONS:

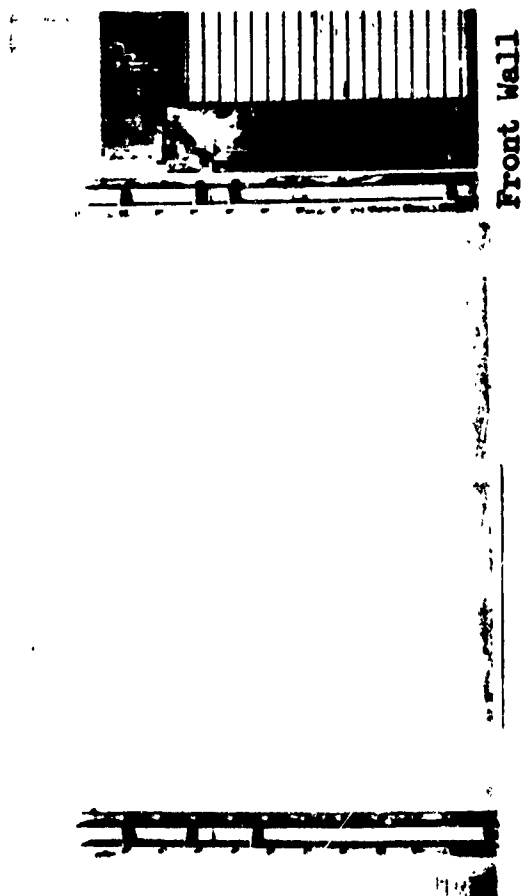
The angles, holding the fibre glass cloth, should not have extended above the bottom of the roof slab or below the top of the floor slab.

## FIELD DAMAGE NOTES:

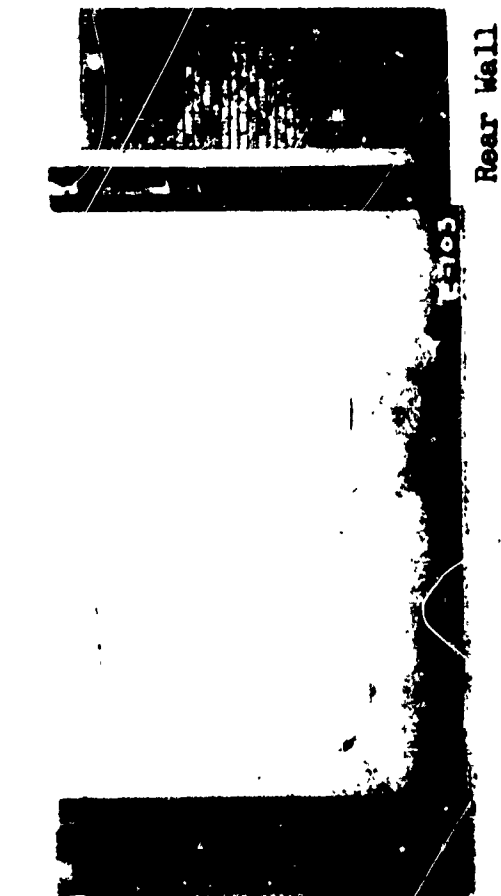
There was no observable damage.

The maximum recorded displacement of the front wall was 0.17 in.

The measured, pre shot, natural frequency of the front wall was 61.6 cps. For the rear wall, the measured, pre shot and post shot, natural frequencies were 39.1 cps and 41.6 cps, respectively.

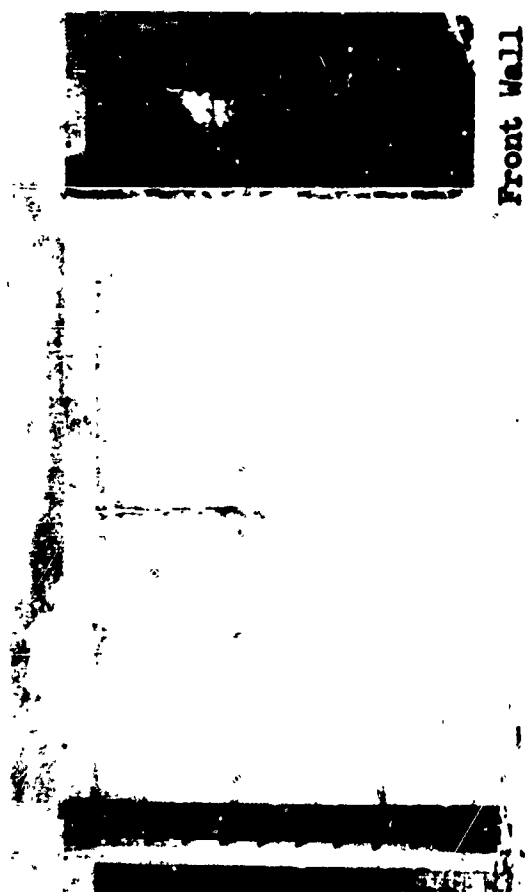


Front Wall



Rear Wall

Fig. 2.41 Pre Shot Photography - Cell No. 14a



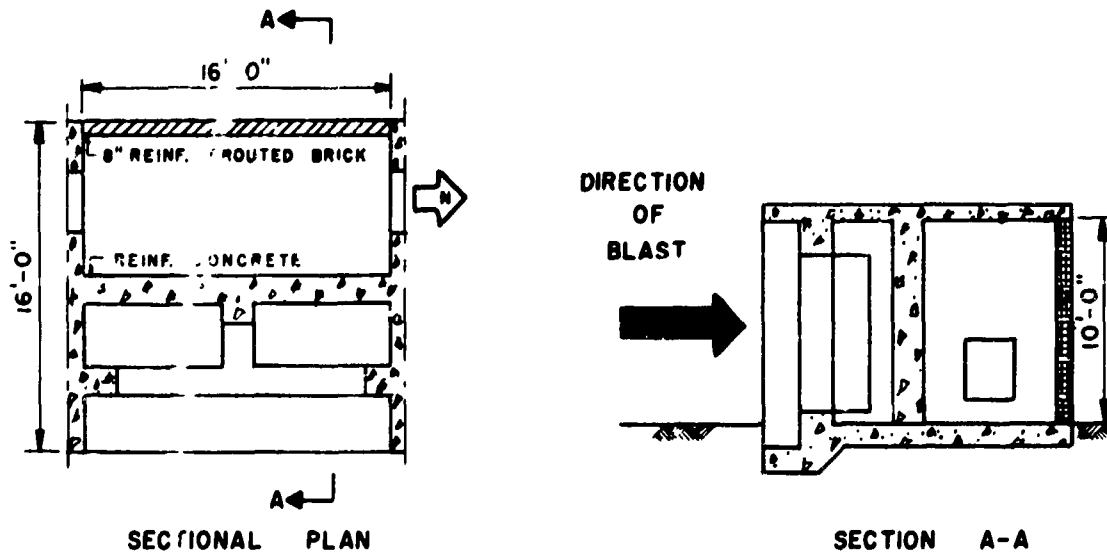
Front Wall



Rear Wall

Fig. 2.42 Post Shot Photography - Cell No. 14a

# CELL NO.15a 10'x16' OPENING



## DESCRIPTION:

The rear wall consisted of 8 in. reinforced grouted brick. Continuous bars were placed from the wall into the floor slab. Each of the side edges had an angle extending from the top of the roof slab to the bottom of the floor slab for a fibre glass cloth blast closure of the joints.

## CONSTRUCTION ERRORS AND OMISSIONS:

A 1/4 in. recess for horizontal bearing of the rear wall should have been provided in the floor and roof slabs. Continuous bars from the walls into the roof slab were omitted. The angles, holding the fibre glass cloth, should not have extended above the bottom of the roof slab or below the top of the floor.

## FIELD DAMAGE NOTES:

The rear wall was displaced outward at the top from 1/4 in., at the north edge, to 3/4 in., at the south edge.

The maximum recorded displacement of the rear wall was 0.32 in.



Pre Shot

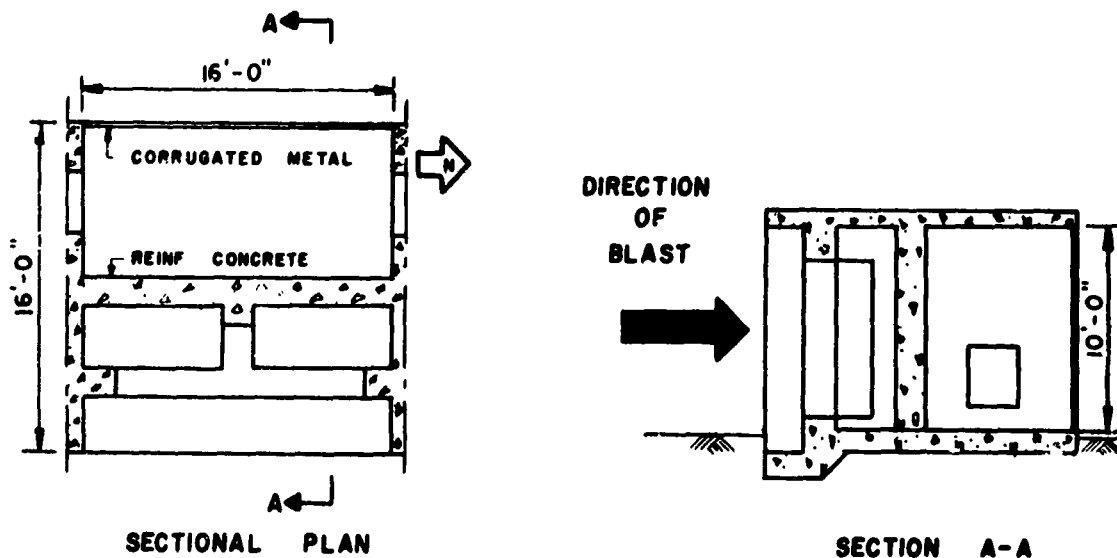
Front Wall Not Tested



Post Shot

Fig. 2.43 Rear Wall - Cell No. 15a

# CELL NO. 16a 10'x16' OPENING



## DESCRIPTION:

The rear wall consisted of 22 gage corrugated metal on structural steel girts spanning horizontally at the roof level and mid-height and a structural steel angle spanning horizontally at the floor level. A 1-1/2 in. opening between the metal and the bottom of the roof slab was covered with fibre glass cloth for blast closure.

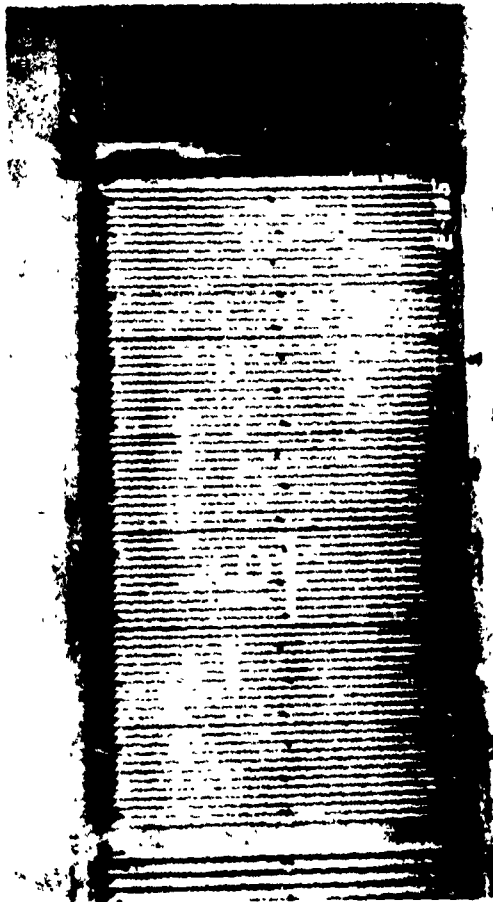
## CONSTRUCTION ERRORS AND OMISSIONS:

None

## FIELD DAMAGE NOTES:

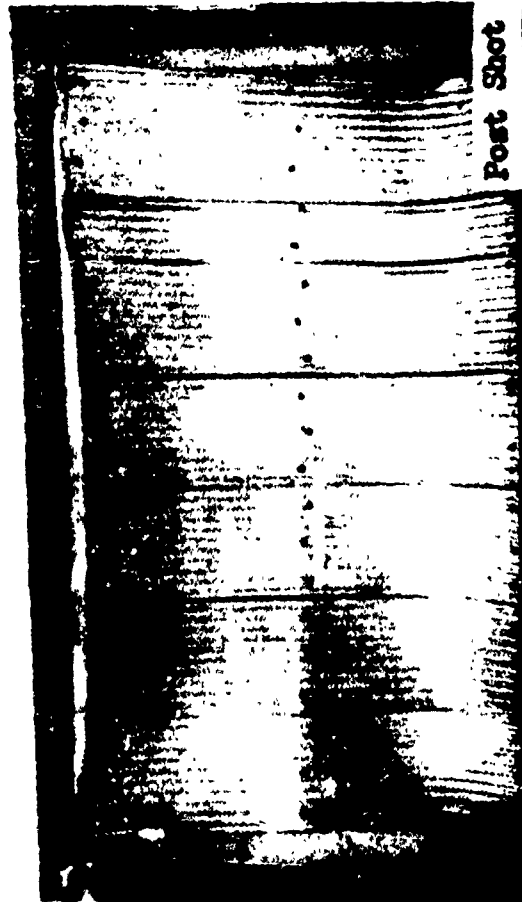
The metal siding was in place but was bowed in from the top to bottom. The middle girt was sheared off its connection at the south edge with sheared bolts remaining in the wall. The bottom angle was ripped loose and tilted back 45°. The top girt was slightly bowed in.





Pre Shot

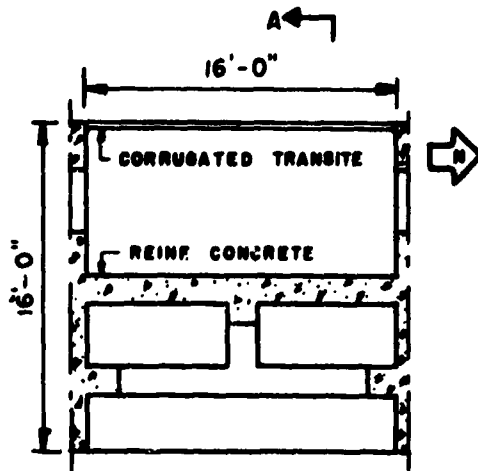
Front Wall Not Tested



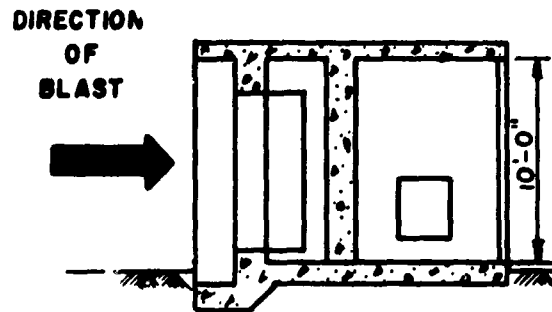
Post Shot

Fig. 2.14 Rear Wall - Cell No. 16a

# CELL NO.17 a 10'x 16' OPENING



SECTIONAL PLAN



SECTION A-A

## DESCRIPTION:

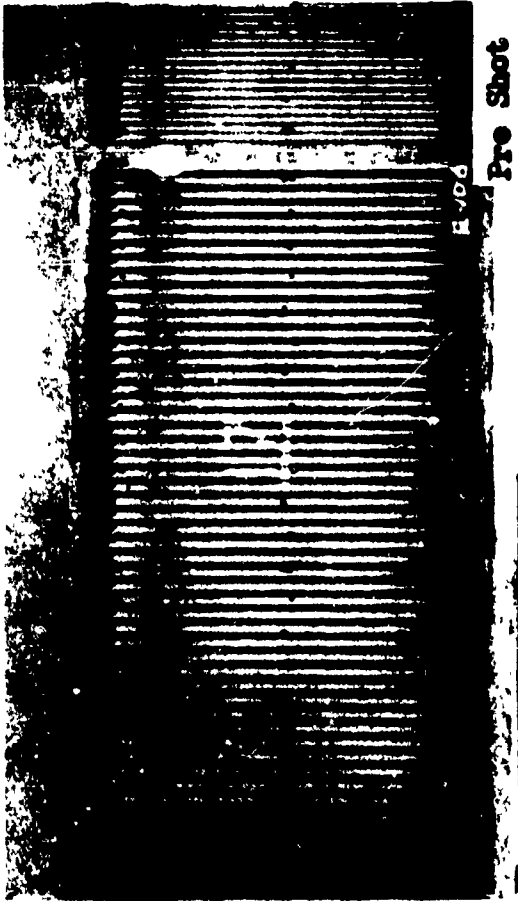
The rear wall consisted of corrugated cement asbestos on structural steel girts spanning horizontally at the roof level and mid-height and a structural steel angle spanning horizontally at the floor level. A 1-1/2 in. opening between the corrugated siding and the bottom of the roof slab was covered with fibre glass cloth for blast closure.

## CONSTRUCTION ERRORS AND OMISSIONS:

None

## FIELD DAMAGE NOTES:

All the cement asbestos was broken off with the middle girt bowed in about 6 in. at the center. The bottom girt anchor bolts were broken out of the slab at several points.

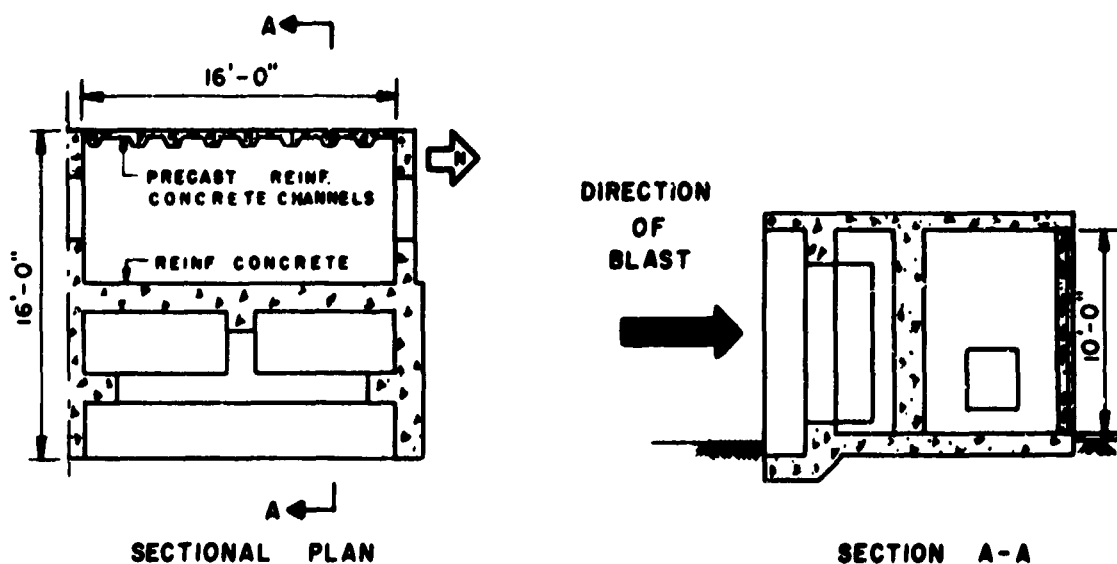


Front Wall Not Tested



Fig. 2.45 Rear Wall - Cell No. 17a

# CELL NO. 18a 10'x16' OPENING



## DESCRIPTION:

The rear wall consisted of precast concrete channel slabs with the top and bottom bearing against and bolted to angles. There was a 1 in. gap between the top of the wall and the bottom of the roof slab. Each of the side edges had an angle extending from the top of the roof slab to the bottom of the floor slab for a fibre glass cloth blast closure of the joints.

## CONSTRUCTION ERRORS AND OMISSIONS:

The angles, holding the fibre glass cloth, should not have extended above the bottom of the roof slab or below the top of the floor slab.

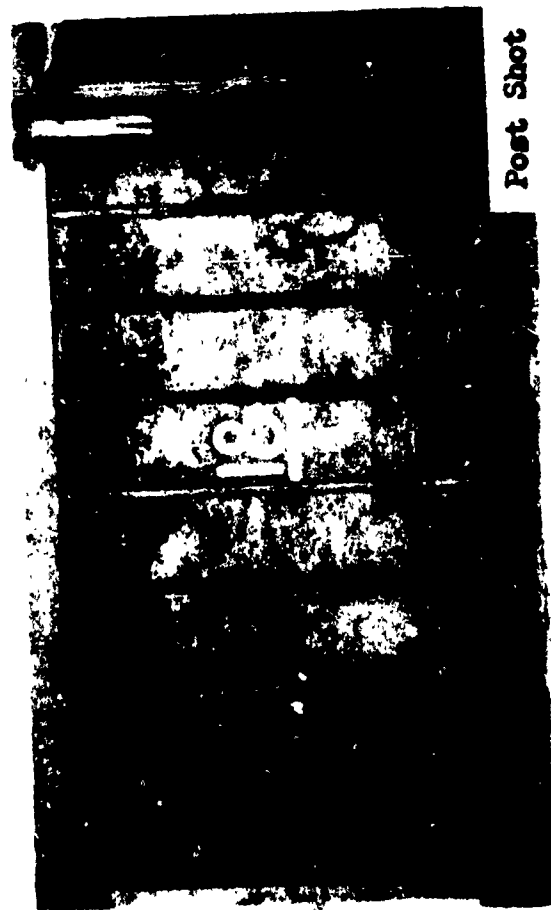
## FIELD DAMAGE NOTES:

On the inside face some hair cracks in the edges of the flanges and cracking vertically down the middle of the webs were found. In one case a flange was cracked 4 ft vertically down the inside at about the middle of the flange width.

The measured, pre shot and post shot, natural frequencies of the rear wall were 24.0 cps and 15.0 cps, respectively.



Pre Shot

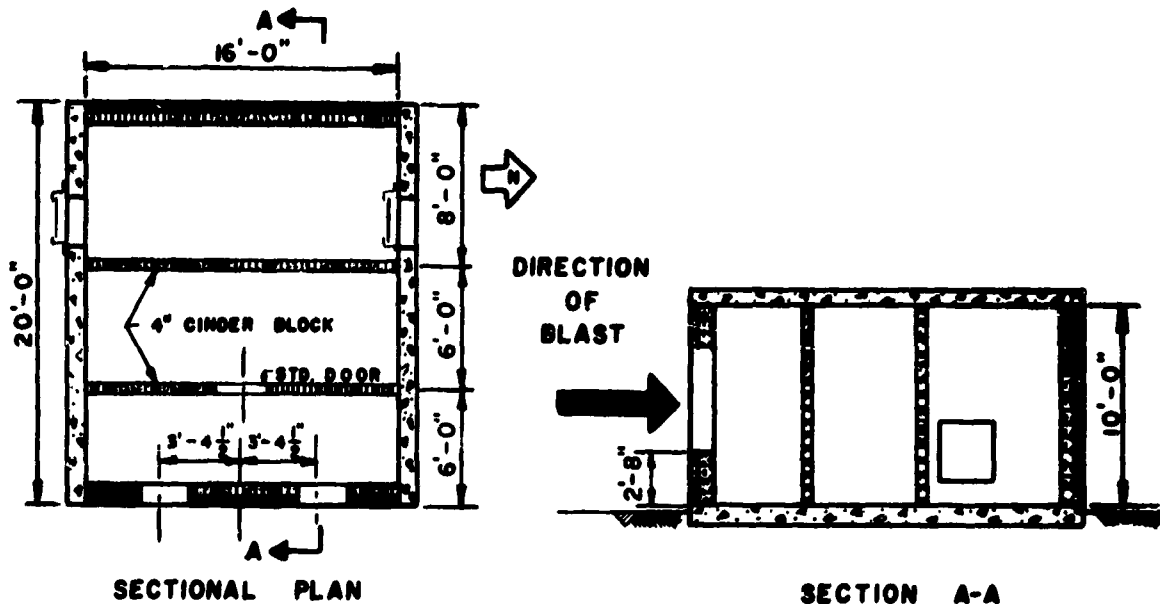


Post Shot

Fig. 2.46 Rear Wall - Cell No. 18a

Front Wall Not Tested

# CELL NO. 1b 10'x16' OPENING



## DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing and 8 in. cinder block backing. There were two windows in the front wall, 3 ft 3 in. by 5 ft 5 in. The partitions were 4 in. cinder block with 3/4 in. plaster on each face. The partitions had mortar joints at the top and bottom, and dovetail anchors and mortar joints at the side edges. The front partition had a standard, 3 ft by 6 ft 8 in., door in the center.

## CONSTRUCTION ERRORS AND OMISSIONS:

None

## FIELD DAMAGE NOTES:

The front partition had its door torn out and was badly cracked. It was slightly bowed.

The rear partition was destroyed except for the bottom and top fillets. The debris was piled 2 to 3 pieces high.

The front wall was spalled at the top on the outside face. The window frames were bowed in slightly at the cross rail.

The rear wall was marked on the inside face and spalled on the outside face at the top, north edge.

The measured, pre shot, natural frequency of the front wall was 36.1 cps. For the rear wall, the measured, pre shot and post shot, natural frequencies were 36.1 cps and 19.8 cps, respectively.

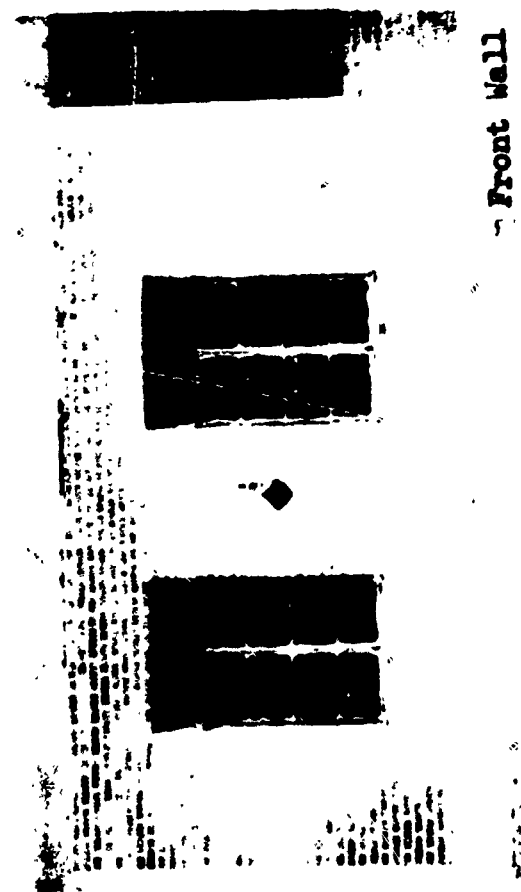


Front Wall



Rear Wall

Fig. 2.47 Pre Shot Photography - Cell No. 1b



Front Wall



Rear Wall

Fig. 2.48 Post Shot Photography - Cell No. 1b

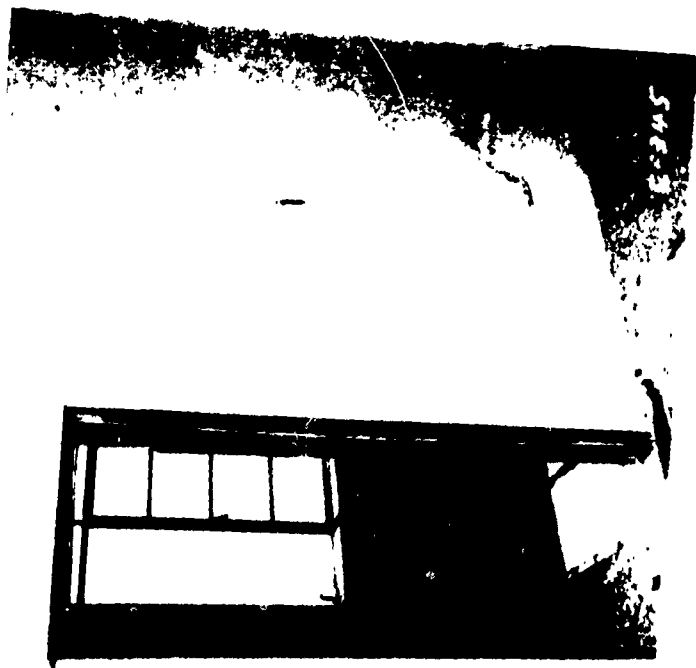


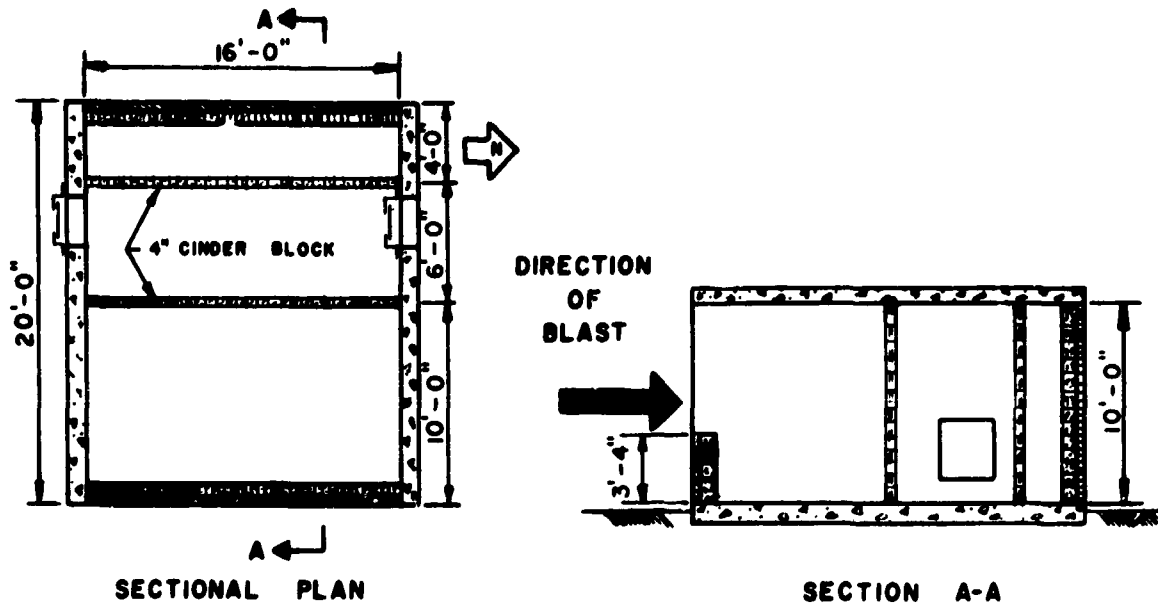
Fig. 2.49 Post Shot - Interior - Cell No. 1b



Fig. 2.50 Post Shot - Interior - Cell No. 1b



## CELL NO.2b 10'x16' OPENING



### DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing and 8 in. cinder block backing. The front wall was 3 ft 4 in. high. The partitions were 4 in. cinder block with 3/4 in. plaster on each face. The partitions had mortar joints at the top and bottom, and dovetail anchors and mortar joints at the side edges.

### CONSTRUCTION ERRORS AND OMISSIONS:

There was a poor mortar joint between the top course of the rear wall and the bottom of the roof slab.

### FIELD DAMAGE NOTES:

The partitions were destroyed except for fillets at the top and bottom. The debris was deposited behind the front partition.

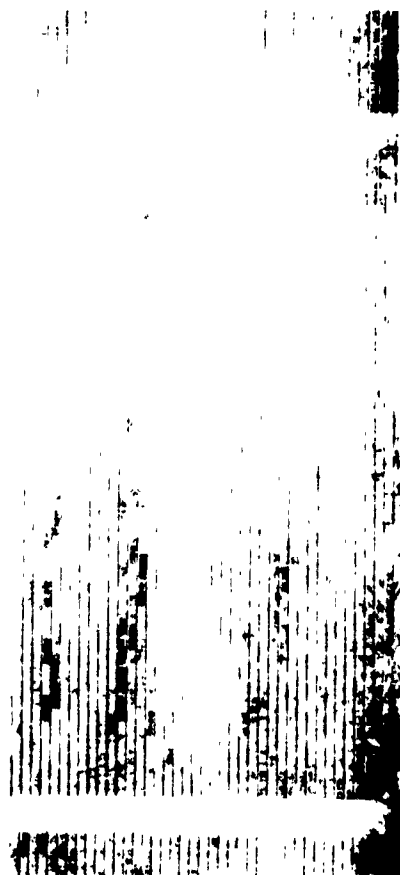
The front wall had a vertical hairline crack, on the outside face, running from the top to the ground, at the center, with slight spalling at the bottom. The inside face was cracked vertically from the top to the bottom, at the center.

The rear wall was badly marked by debris on the inside face. There was a 1 in. gap on the inside face between the top of the wall and the roof slab for 2/3 of the joint. The outside face was spalled at the top and bottom and the upper north edge.

The measured, pre shot and post shot, natural frequencies of the rear wall were 46.5 cps and 19.2 cps, respectively.



Front Wall



Rear Wall



Front Wall



Rear Wall

Fig. 2.51 Pre Shot Photography - Cell No. 2b

Fig. 2.52 Post Shot Photography - Cell No. 2b

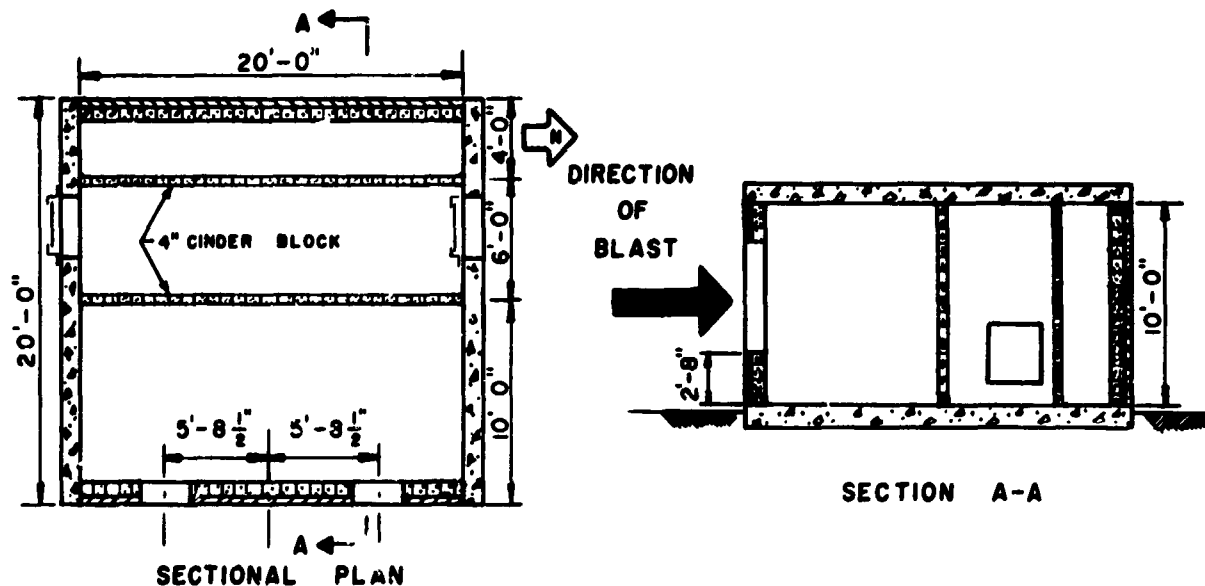


Fig. 2.54 Post Shot - Interior - Cell No. 2b



Fig. 2.53 Post Shot - Rear Wall  
Interior - Cell No. 2b

# CELL NO. 3b 10'x20' OPENING



## DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing and 8 in. cinder block backing. There were two windows in the front wall, 3 ft 3 in. by 5 ft 5 in. The partitions were 4 in. cinder block with 3/4 in. plaster on each face. The partitions had mortar joints at the top and bottom, and dovetail anchors and mortar joints at the side edges.

## CONSTRUCTION ERRORS AND OMISSIONS:

A post shot examination indicated that the mortar was placed on dirty floor and roof slabs, probably without wetting causing little or no bond between the partitions and the slabs. There was no mortar between top course of block and the roof slab for 2/3 of the rear wall.

## FIELD DAMAGE NOTES:

The partitions were destroyed except for fillets. The dovetail anchors were pulled out of the slots.

The front wall had a vertical hair crack in the block above one window, on the inside face. The outside face has slight cracks at the joints with the top slightly spalled and bowed in 1/8 in. to 1/4 in. at the center. The window frames were slightly bowed in.

The rear wall was bowed in 1/4 in. to 1/2 in. at the top and bottom center. Nearly all the mortar at the top joint of rear wall was pushed out.

The measured, pre shot and post shot, natural frequencies of the front wall were 35.4 cps and 13.9 cps, respectively. For the rear wall, the measured, pre shot and post shot, natural frequencies of the rear wall were 50.8 cps and 27.3 cps, respectively.



Front Wall

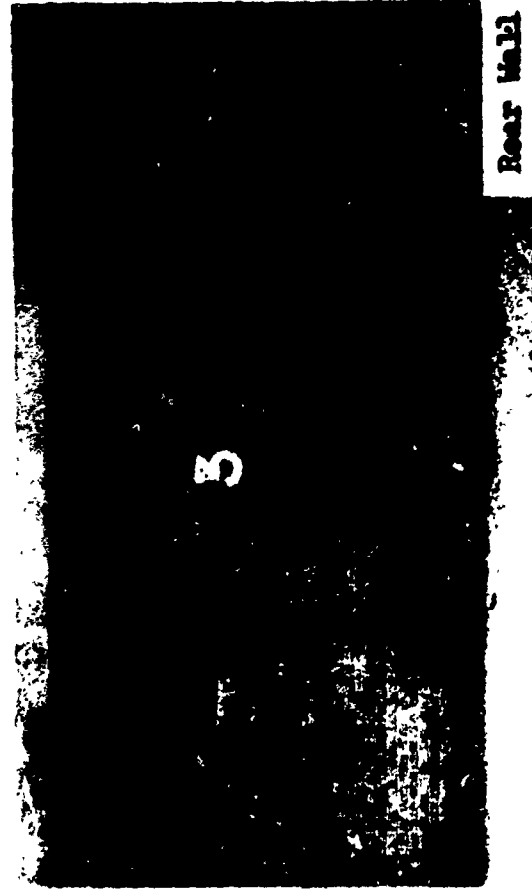


Rear Wall

Fig. 2.55 Pre Shot Photography - Cell No. 3b



Front Wall



Rear Wall

Fig. 2.56 Post Shot Photography - Cell No. 3b

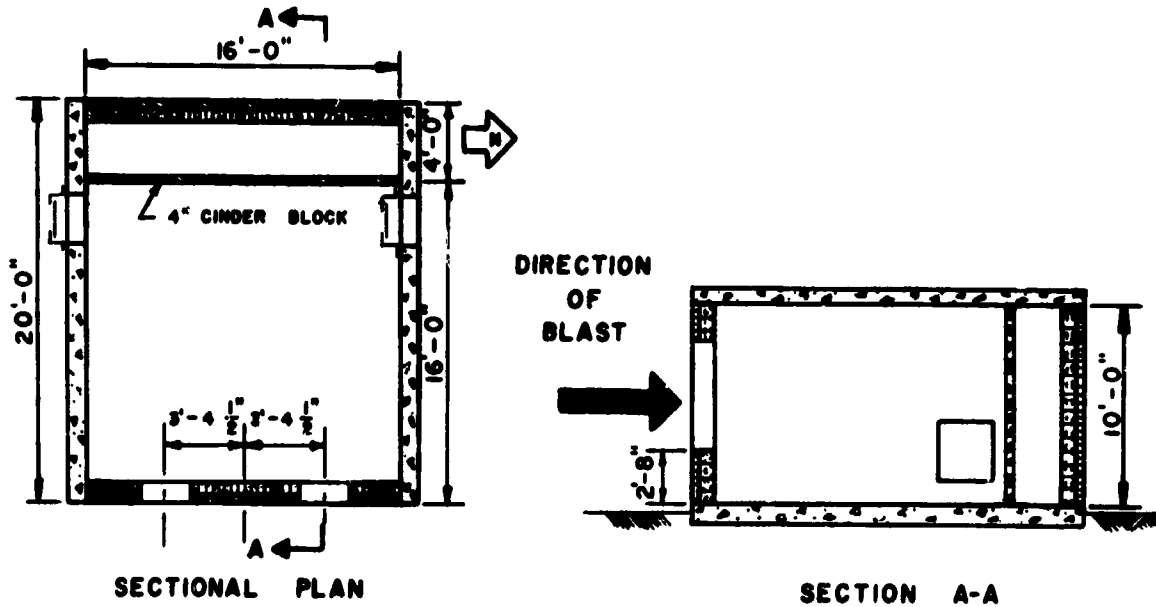


Fig. 2.57 Post Shot - Front Wall Detail  
Cell No. 3b



Fig. 2.58 Post Shot - Interior - Cell No. 3b

# CELL NO. 4b 10'x16' OPENING



## DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing and 8 in. cinder block backing. There were two windows in the front wall, 3 ft 3 in. by 5 ft 5 in. The partition was 4 in. cinder block with 3/4 in. plaster on each face. The partition had mortar joints at the top and bottom, and dovetail anchors and mortar joints at the side edges.

## CONSTRUCTION ERRORS AND OMISSIONS:

There was no bond between the top of rear wall and the roof slab.

## FIELD DAMAGE NOTES:

The partition was destroyed except for fillets.

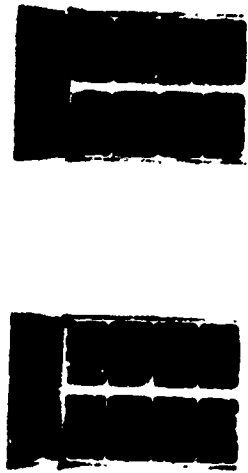
The front wall was bowed out 1/2 in. at the top above the north window. The outside face was spalled at the top edge. The windows were bowed in slightly. The inside face had a horizontal crack in the center section 3 joints above the sills.

The rear wall was spalled at the top edge on the outside face.

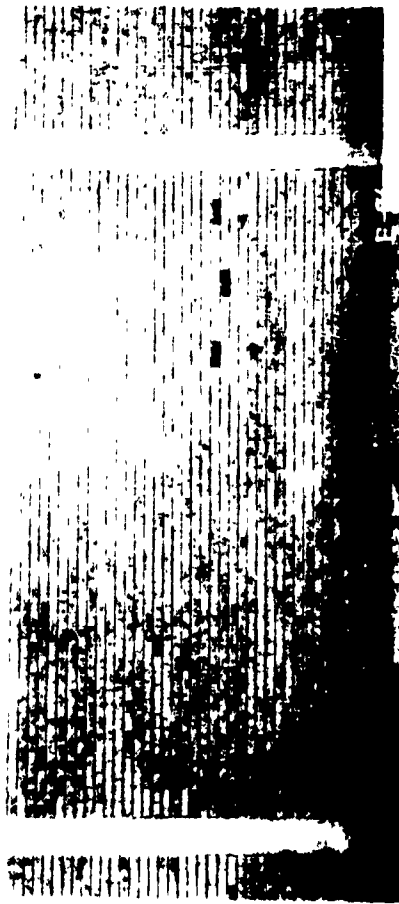
The measured, pre shot and post shot, natural frequencies of the front wall were 33.4 cps and 20.6 cps, respectively. For the rear wall, the measured, pre shot and post shot, natural frequencies were 58.3 cps and 31.2 cps, respectively.



Front Wall



Front Wall



Rear Wall



Rear Wall

Fig. 2.59 Pre Shot Photography - Cell No. 4b

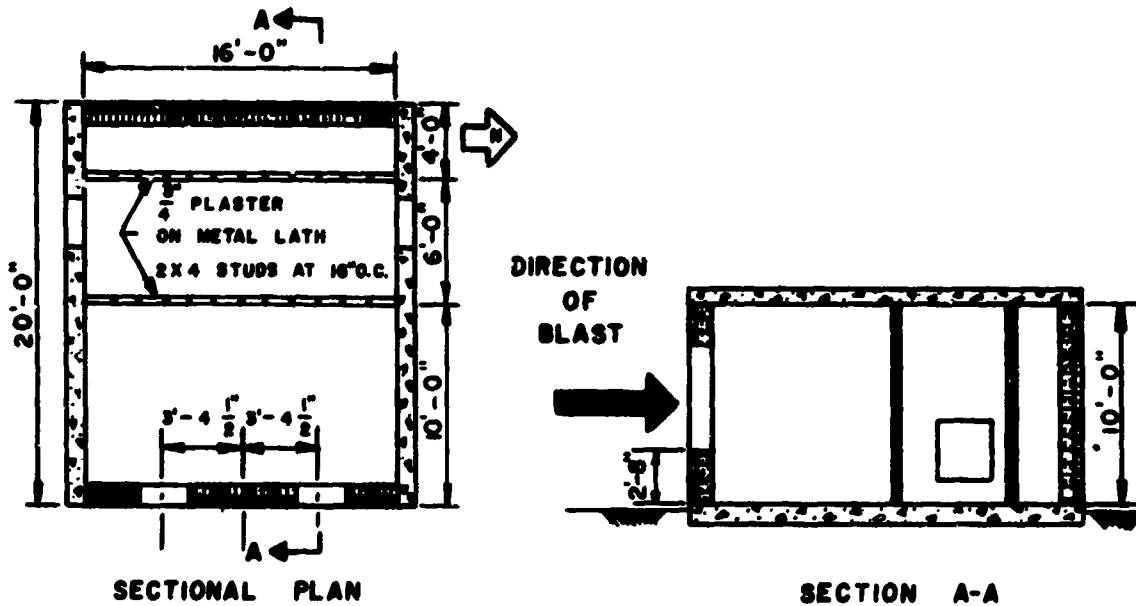
Fig. 2.60 Post Shot Photography - Cell No. 4b





Fig. 2.61 Post Shot - Interior - Cell No. 4b

# CELL NO.5b 10'x16' OPENING



## DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing and 8 in. cinder block backing. There were two windows in the front wall, 3 ft 3 in. by 5 ft 5 in. The partitions consisted of 2 in. by 4 in. wood studs, at 16 in. on centers, with 3/4 in. plaster on metal lath on each face. The partitions had 2 in. by 4 in. plates at the top and bottom.

## CONSTRUCTION ERRORS AND OMISSIONS:

Dovetail anchors at the side edges were omitted. Anchorage of the plates to the roof and floor slabs with cut nails was omitted. The only support was due to the bond of the plaster to the respective surfaces.

## FIELD DAMAGE NOTES:

The partitions were blown over without much movement of the base and remained in one piece although bowed and cracked badly.

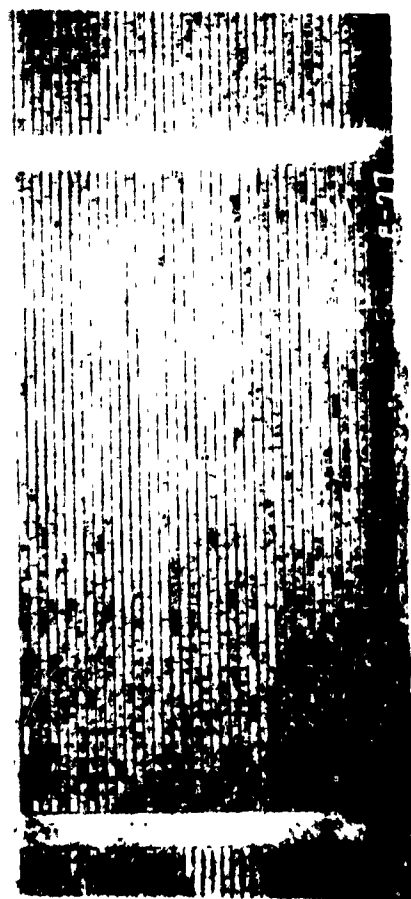
The front wall was spalled at the top, on the outside face, with the window frames bowed in slightly. The inside face had a horizontal crack in the center section, at the 4th mortar joint above the sill.

The rear wall was spalled badly, at the top, south side, on the outside face. The wall was bowed out at the top from nothing at the north edge to 1 in. at the south edge. There was a vertical crack from the top to the center at the south 1/4 point on the outside face. The inside face was covered by the partitions.

The measured, pre shot and post shot, natural frequencies of the front wall were 33.3 cps and 25.0 cps, respectively. For the rear wall, the measured, pre shot and post shot, natural frequencies were 55.3 cps and 12.7 cps, respectively.



Front Wall



Rear Wall

Fig. 2.62 Pre Shot Photography - Cell No. 5b



Front Wall



Rear Wall

Fig. 2.63 Post Shot Photography - Cell No. 5b

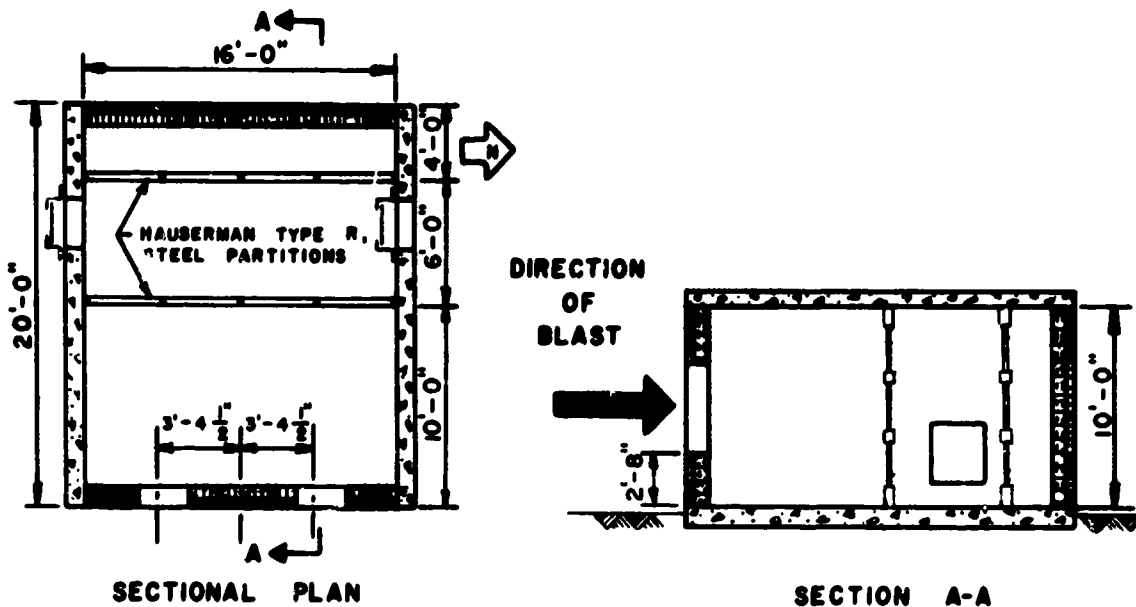


Fig. 2.64 Post Shot - Interior - Cell No. 5b



Fig. 2.65 Post Shot - Interior - Cell No. 5b

# CELL NO.6b 10'x16' OPENING



## DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing and 8 in. cinder block backing. There were two windows in the front wall, 3 ft 3 in. by 5 ft 5 in. The partitions were Hauserman Type R, steel, partitions with middle section glazed. There were four nailed inserts in the end walls and five nailed inserts in the floor slab.

## CONSTRUCTION ERRORS AND OMISSIONS:

None

## FIELD DAMAGE NOTES:

The partitions were blown back intact, except for bowing and complete glass breakage. The bases of the partitions were displaced 2 ft to the rear.

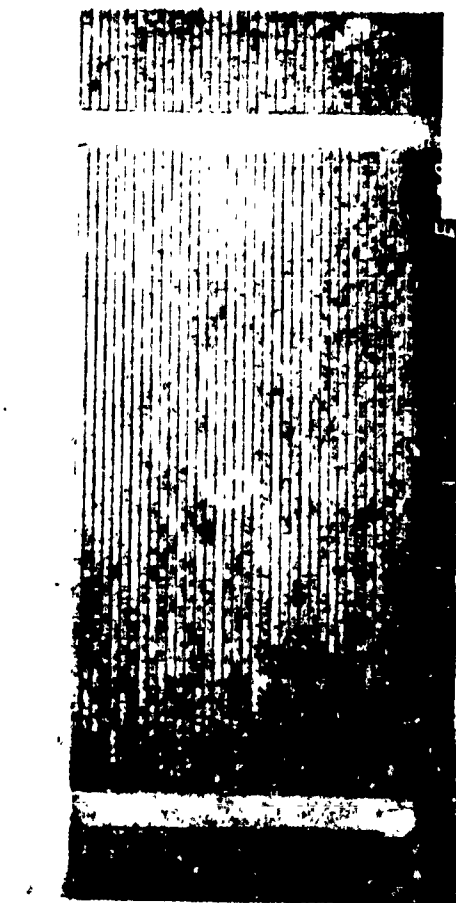
The front wall was spalled at the top on the outside face.

The rear wall was slightly spalled at the top on the outside face. The inside face was covered by the partitions.

The measured, pre shot and post shot, natural frequencies of the front wall were 34.2 cps and 21.9 cps, respectively. For the rear wall, the measured, pre shot and post shot, natural frequencies were 41.1 cps and 31.5 cps, respectively.

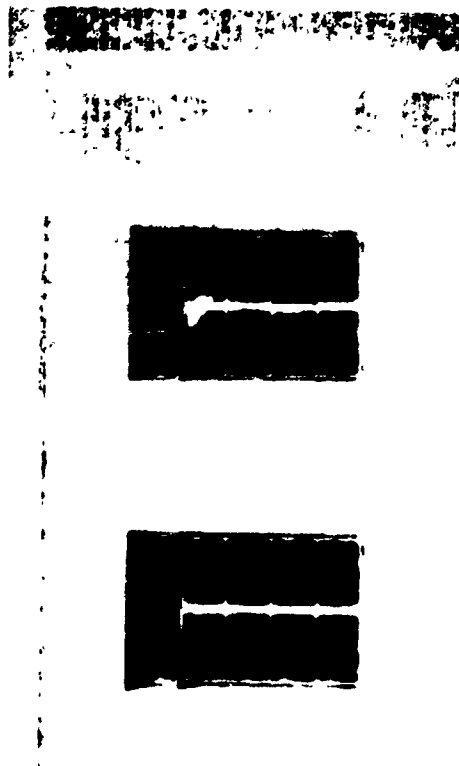


Front Wall



Rear Wall

Fig. 2.66 Pre Shot Photography - Cell No. 6b



Front Wall



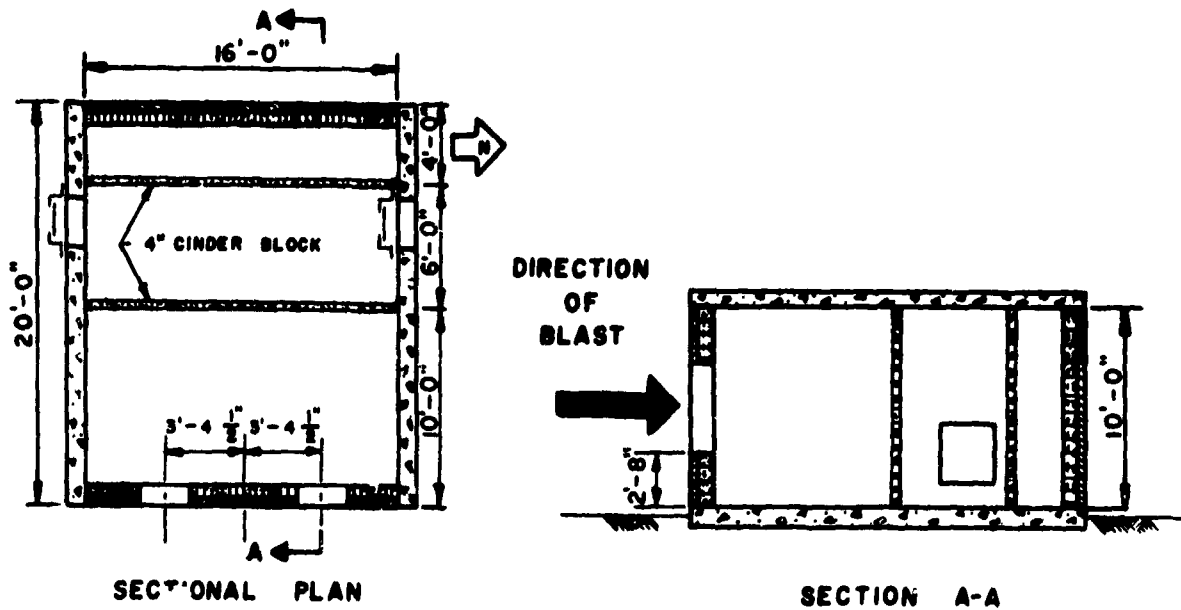
Rear Wall

Fig. 2.67 Post Shot Photography - Cell No. 6b



Fig. 2.68 Post Shot - Interior - Cell No. 6b

# CELL NO.7b 10'x16' OPENING



## DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing and 8 in. cinder block backing. There were two windows in the front wall, 3 ft 3 in. by 5 ft 5 in. The partitions were 4 in. cinder block with 3/4 in. plaster on each face. The partitions had angles at the top and bottom on each face, which were anchored to the roof and floor slabs. There were dovetail anchors and mortar joints at the side edges.

## CONSTRUCTION ERRORS AND OMISSIONS:

None

## FIELD DAMAGE NOTES:

The front partition was 95 percent destroyed.

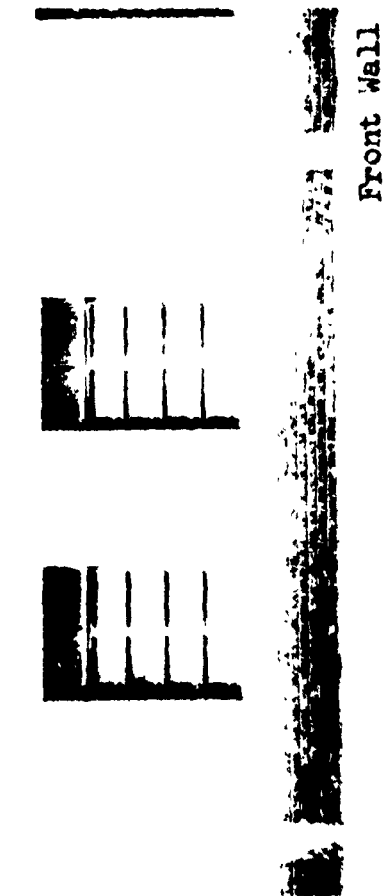
The rear partition was 75 percent destroyed.

The front wall was slightly spalled at the top on the outside face. The window frames were bowed in.

The rear wall was slightly spalled at the top on the outside face.

The measured, pre shot and post shot, natural frequencies of the front wall were 38.4 cps and 21.8 cps, respectively. For the rear wall, the measured, pre shot and post shot, natural frequencies were 47.1 cps and 24.0 cps respectively.





96



Fig. 2.69 Pre Shot Photography - Cell No. 7b

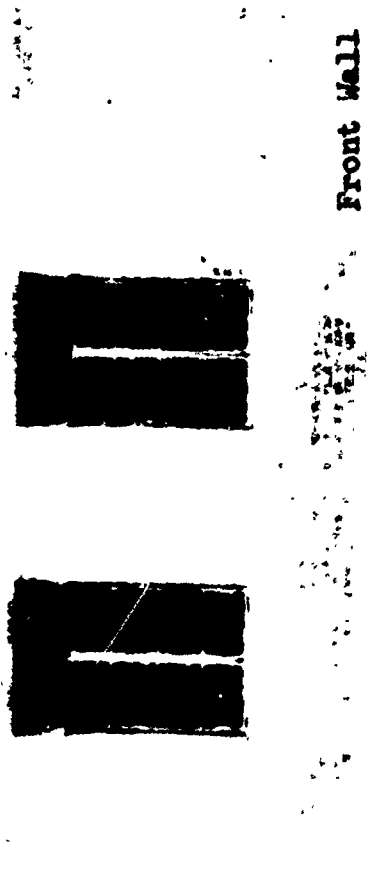
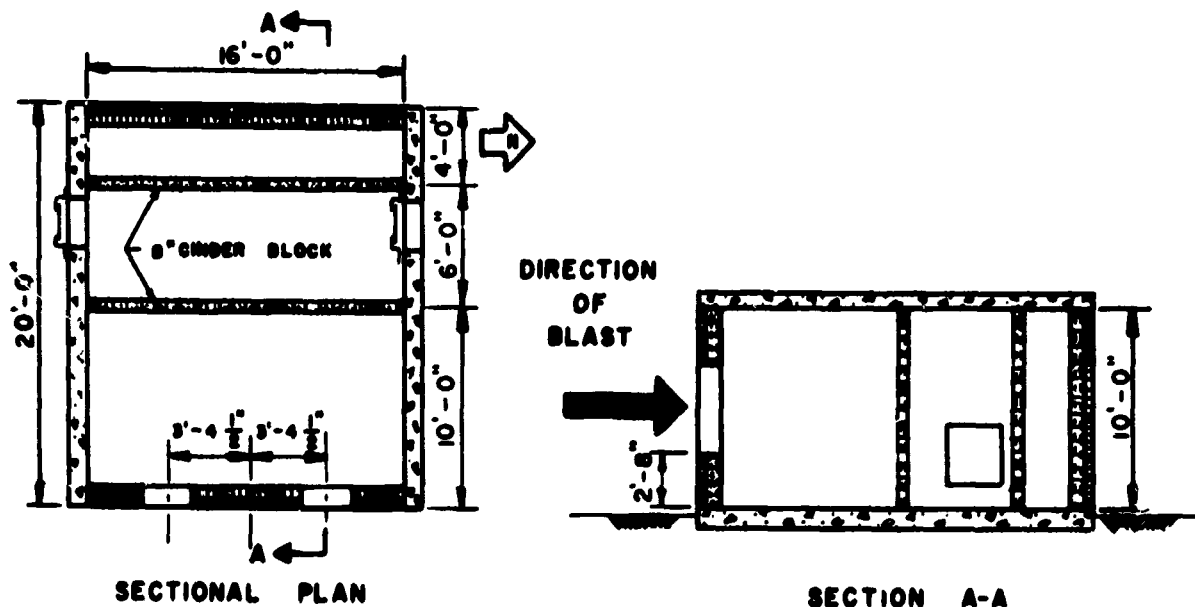


Fig. 2.70 Post Shot Photography - Cell No. 7b



Fig. 2.71 Post Shot - Interior - Cell No. 7b

# CELL NO. 8b 10'x16' OPENING



## DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing and 8 in. cinder block backing. There were two windows in the front wall, 3 ft 3 in. by 5 ft 5 in. The partitions were 8 in. cinder block with 3/4 in. plaster on each face. The partitions had mortar joints at the top and bottom and dovetail anchors and mortar joints at the side edges.

## CONSTRUCTION ERRORS AND OMISSIONS:

None

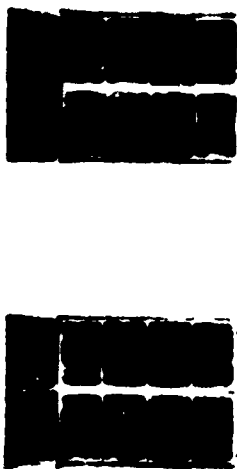
## FIELD DAMAGE NOTES:

The front partition had 2 horizontal cracks and a diagonal crack on the front face with some cracking on the rear face. There was some slight displacement of the front partition.

The rear partition had a hair crack at the center of the front face.

The front wall had a hair crack at the horizontal joint of the center section above the sill, on the inside face. The outside face was spalled at the top. The window frames were bowed in.

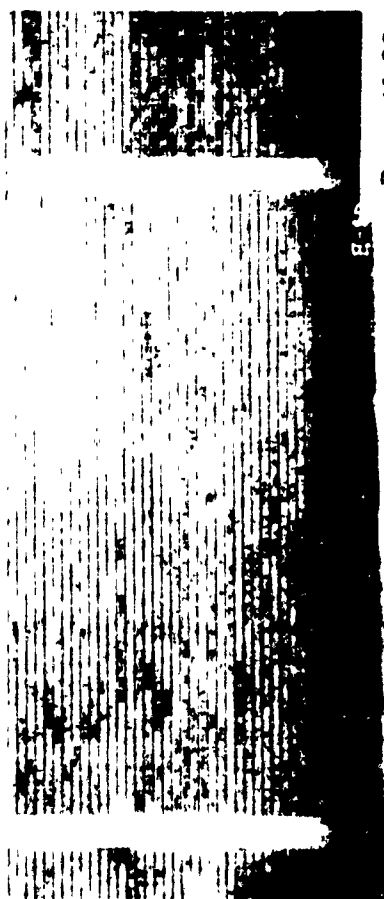
The measured, pre shot and post shot, natural frequencies of the front wall were 38.2 cps and 23.8 cps, respectively. For the rear wall, the measured, pre shot and post shot, natural frequencies were 50.0 cps and 47.4 cps, respectively.



Front Wall



Front Wall



Rear Wall



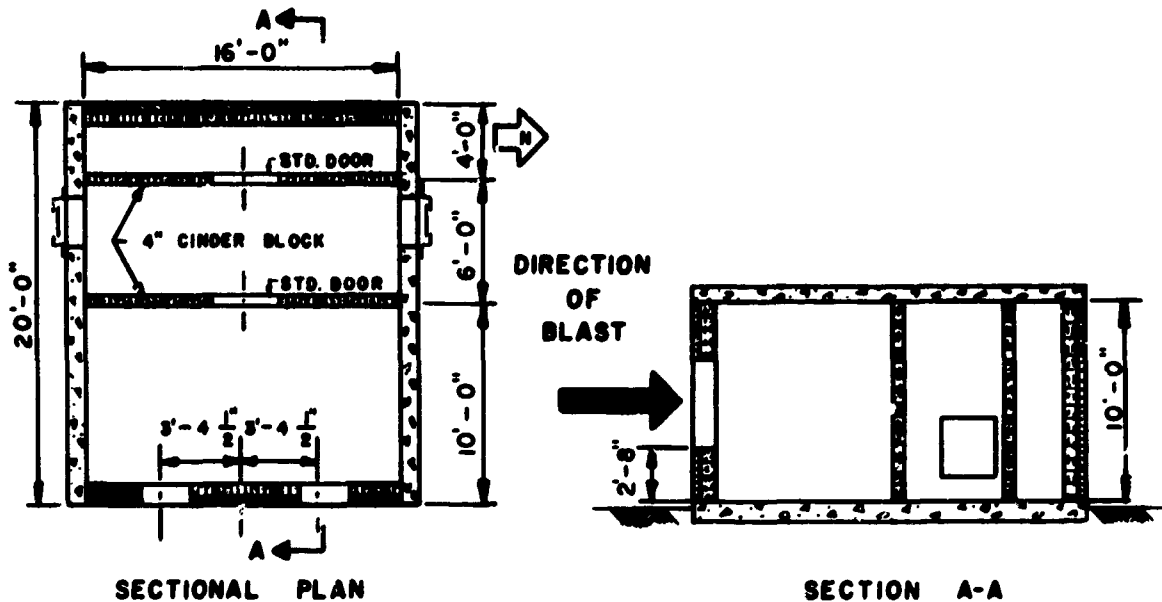
Rear Wall

Fig. 2.72 Pre Shot Photography - Cell No. 8b

Fig. 2.73 Post Shot Photography - Cell No. 8b

Fig. 2.74 Post Shot - Interior - Cell No. 8b

# CELL NO.9b 10' x 16' OPENING



## DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing with 8 in. cinder block backing. There were two windows in the front wall, 3 ft 3 in. by 5 ft 5 in. The partitions were 4 in. cinder block, with standard, 3 ft by 6 ft 8 in., doors placed in the center, and 3/4 in. plaster on each face. The partitions had mortar joints at the top and bottom and dovetail anchors and mortar joints at the side edges.

## CONSTRUCTION ERRORS AND OMISSIONS:

The roof had a 1 in. overhang over the front wall.

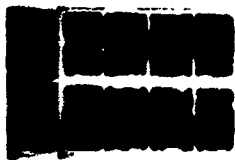
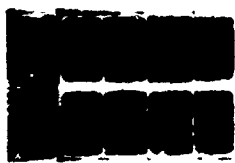
## FIELD DAMAGE NOTES:

The partitions were cracked diagonally from the corners and horizontally. There was no appreciable displacement of the partitions but the doors were badly damaged. The front door was open and the rear door closed.

The front wall was spalled at the top of the outside face. The inside face had a hair crack in the 2nd joint above the sill in the center section.

The rear wall was considerably spalled at the top on the outside face.

The measured, pre shot and post shot, natural frequencies of the front wall were 36.3 cps and 26.4 cps, respectively. For the rear wall, the measured, pre shot and post shot, natural frequencies were 37.5 cps and 24.3 cps, respectively.



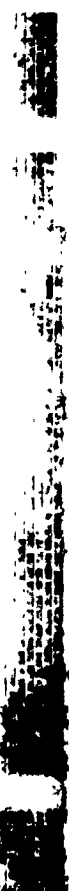
Front Wall



Front Wall



Rear Wall



Rear Wall



Fig. 2.75 Pre Shot Photography - Cell No. 9b

Fig. 2.76 Post Shot Photography - Cell No. 9b

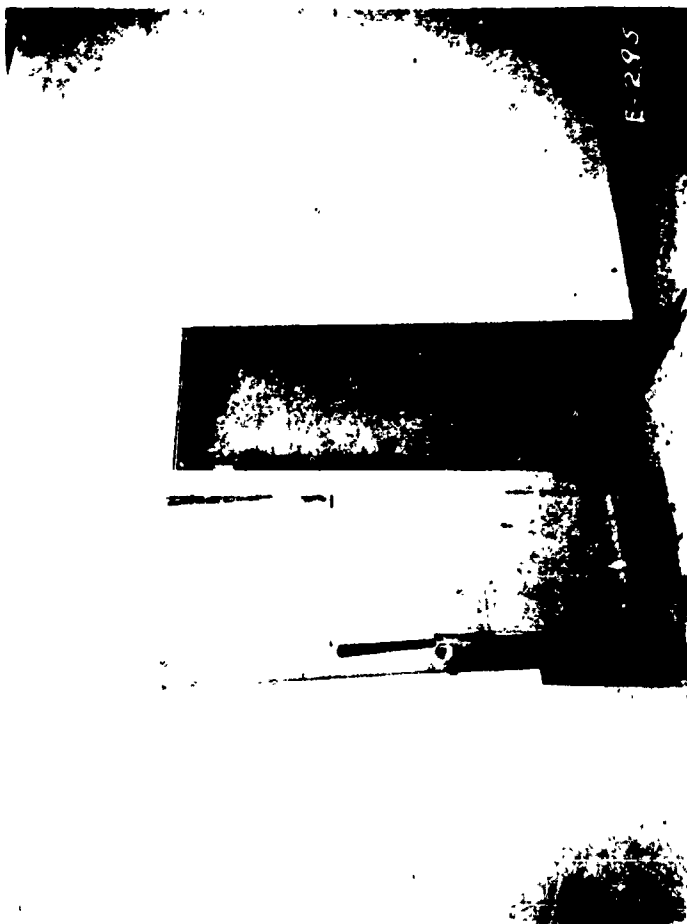
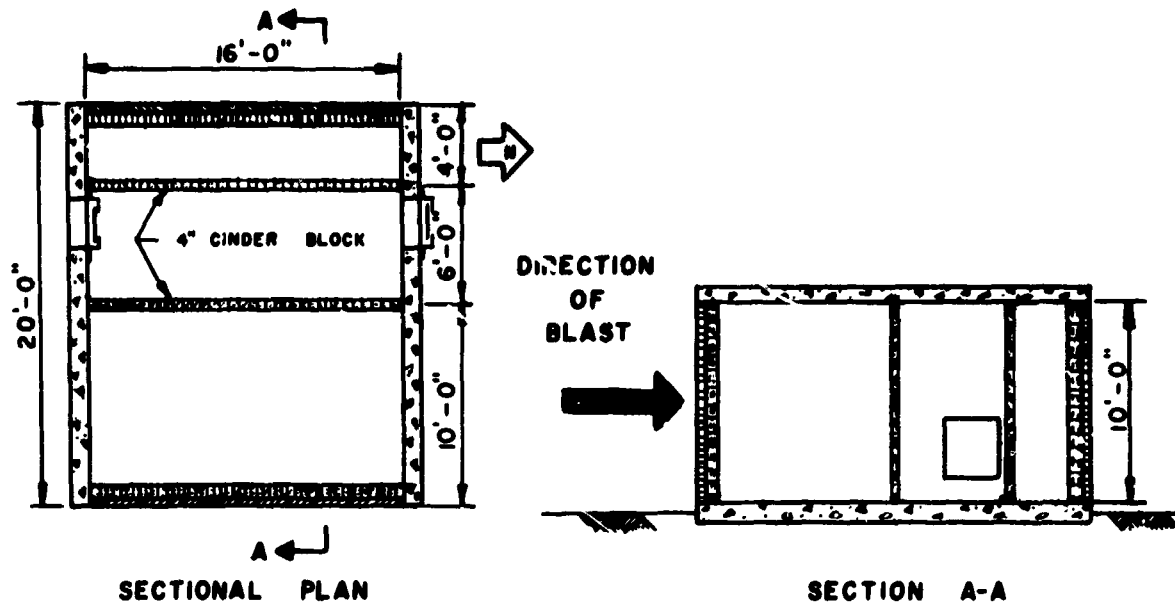


Fig. 2.77 Post Shot - Interior - Cell No. 9b



# CELL NO. 10b 10'x16' OPENING



## DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing and 8 in. cinder block backing. The partitions were 4 in. cinder block with 3/4 in. plaster on each face. The partitions had mortar joints at the top and bottom and dovetail anchors and mortar joints at the side edges.

## CONSTRUCTION ERRORS AND OMISSIONS:

None

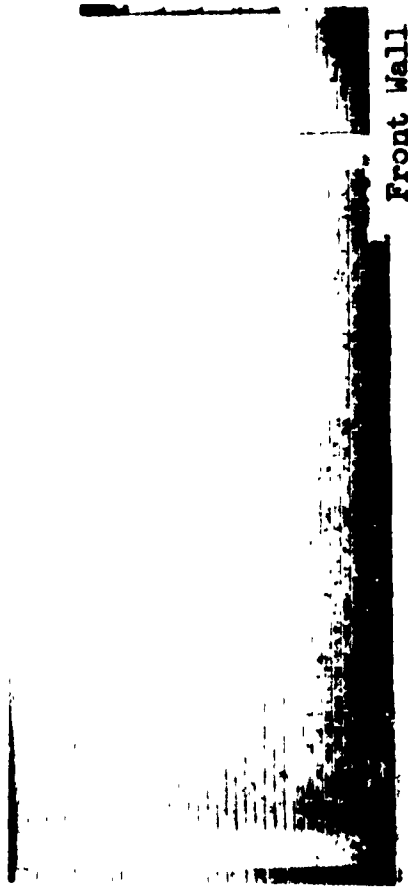
## FIELD DAMAGE NOTES:

The partitions had vertical cracks down the center.

The front wall was badly spalled at the top and the side edges on the outside face. The top of the front wall was bowed in 3/8 in. at the center.

The rear wall was slightly spalled at the top on the outside face.

The measured, pre shot and post shot, natural frequencies of the front wall were 54.5 cps and 33.6 cps, respectively. For the rear wall, the measured, pre shot and post shot, natural frequencies were 54.0 cps and 51.8 cps, respectively.



Front Wall



Rear Wall

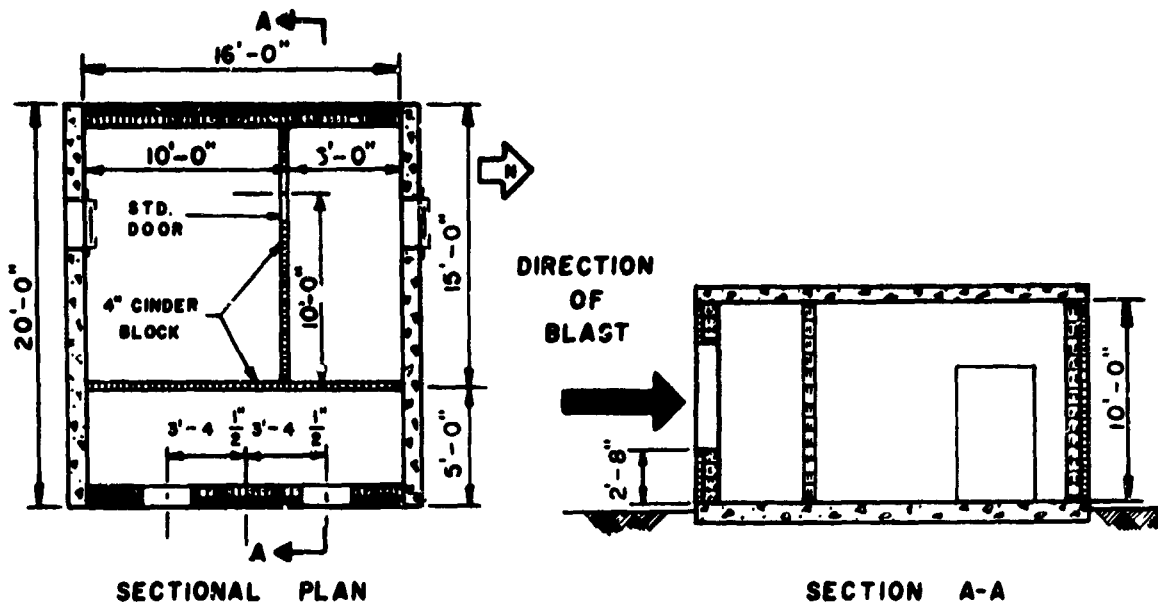
Fig. 2.78 Pre Shot Photography - Cell No. 10b



Front Wall

Fig. 2.79 Post Shot Photography - Cell No. 10b

# CELL NO.11b 10'x16' OPENING



## DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing and 8 in. cinder block backing. There were two windows in the front wall, 3 ft 3 in. by 5 ft 5 in. The two partitions (perpendicular to each other) were 4 in. cinder block with 3/4 in. plaster on each face. The rear partition had standard, 3 ft by 6 ft 8 in., door near one end. The partitions had mortar joints at the top and bottom and dovetail anchors and mortar joints at the side edges.

## CONSTRUCTION ERRORS AND OMISSIONS:

None

## FIELD DAMAGE NOTES:

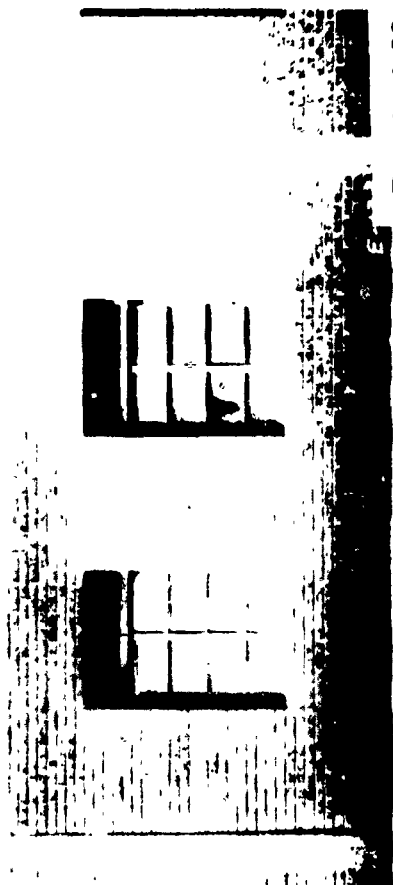
The south section of the front partition was destroyed except for fillets. The north section of the front partition was bowed slightly toward the front and cracked vertically at the center.

The rear partition door frame, front section, was damaged. The door was open with the upper panel blown out.

The front wall was cracked on the inside face at a mortar joint 4 cinder blocks up from the bottom in the center section. The outside face was cracked opposite the crack on the inside face. The window frames were bowed in.

The rear wall, south section, had a few medium punched holes into the cinder block cells on the inside face with a vertical hair crack at the top right. The outside face was slightly spalled at the top.

The measured, pre shot and post shot, natural frequencies of the rear wall were 37.5 cps and 29.7 cps, respectively.

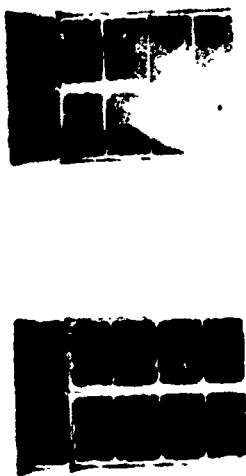


Front Wall



Rear Wall

Fig. 2.80 Pre Shot Photography - Cell No. 11b



Front Wall



Rear Wall

Fig. 2.81 Post Shot Photography - Cell No. 11b



Fig. 2.82 Post Shot - Interior - Small Room - Cell No. 11b

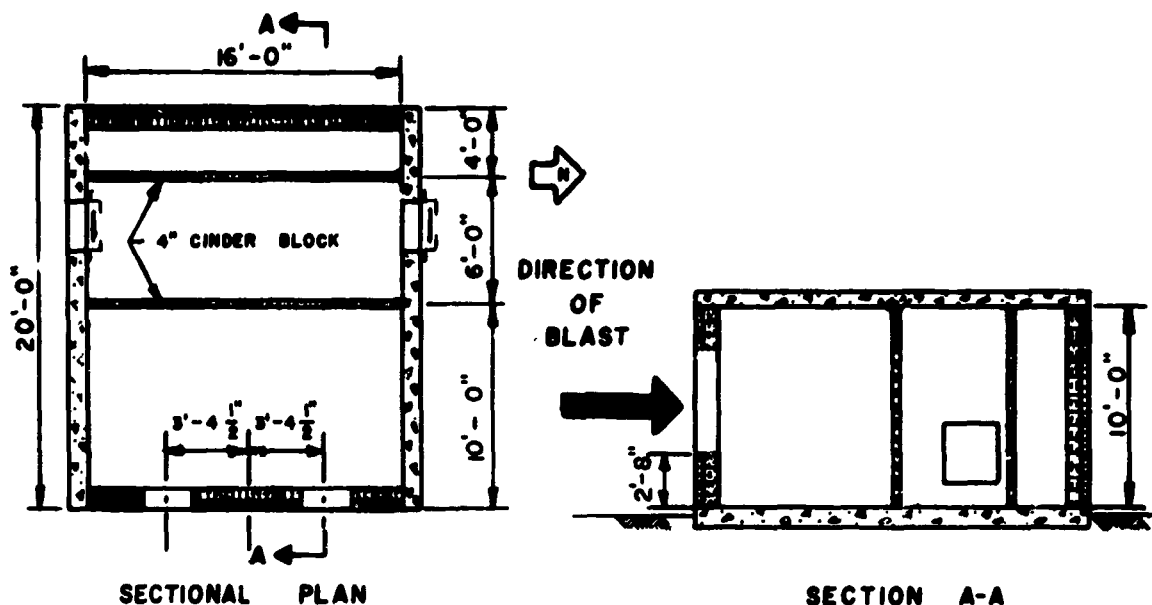


Fig. 2.83 Post Shot - Interior - Cell No. 11b



Fig. 2.84 Post Shot - Door Detail - Cell No. 11b

# CELL NO. 12b 10'x16' OPENING



## DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing and 8 in. cinder block backing. There were two windows in the front wall, 3 ft 3 in. by 5 ft 5 in. The partitions were 4 in. cinder block with 3/4 in. plaster on each face. The partitions had mortar joints at the top and bottom and dovetail anchors and mortar joints at the side edges.

## CONSTRUCTION ERRORS AND OMISSIONS:

None

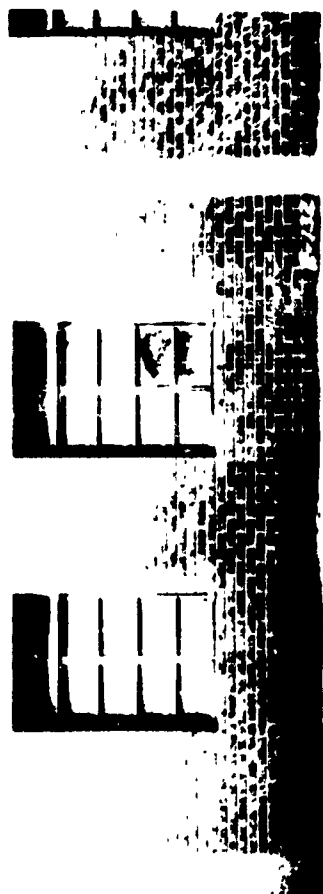
## FIELD DAMAGE NOTES:

The partitions were destroyed except for fillets. A section 5 ft by 6 ft was hanging at the upper, south edge of the rear partition.

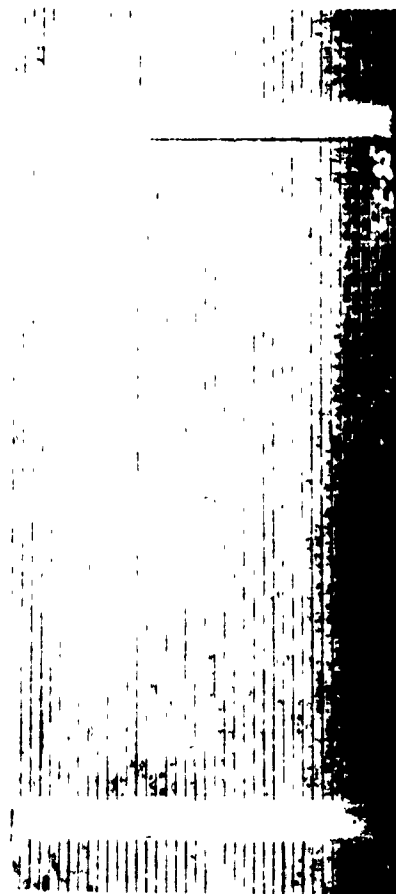
The front wall was spalled at the top on the outside face. The window frames were bowed in.

The rear wall had a vertical hair crack at the center, upper half, on the inside face. The outside face was slightly spalled at the top and bottom.

The measured, pre shot and post shot, natural frequencies of the front wall were 35.6 cps and 27.6 cps, respectively. For the rear wall, the measured, pre shot and post shot, natural frequencies were 56.7 cps and 33.3 cps, respectively.

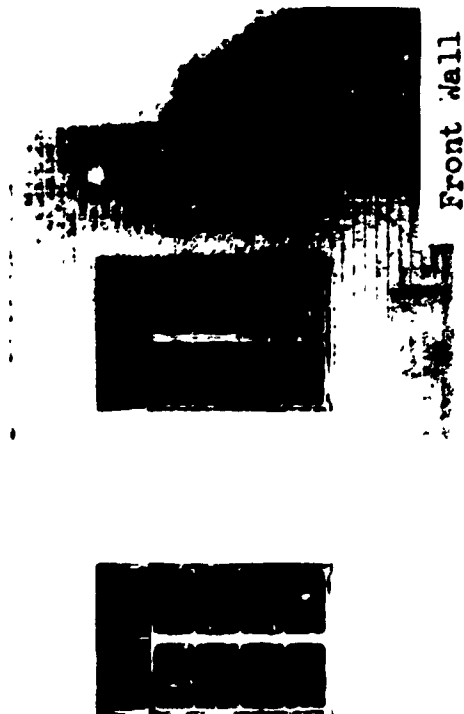


Front Wall



Rear Wall

Fig. 2.85 Pre Shot Photography - Cell No. 12b



Front Wall



Rear Wall

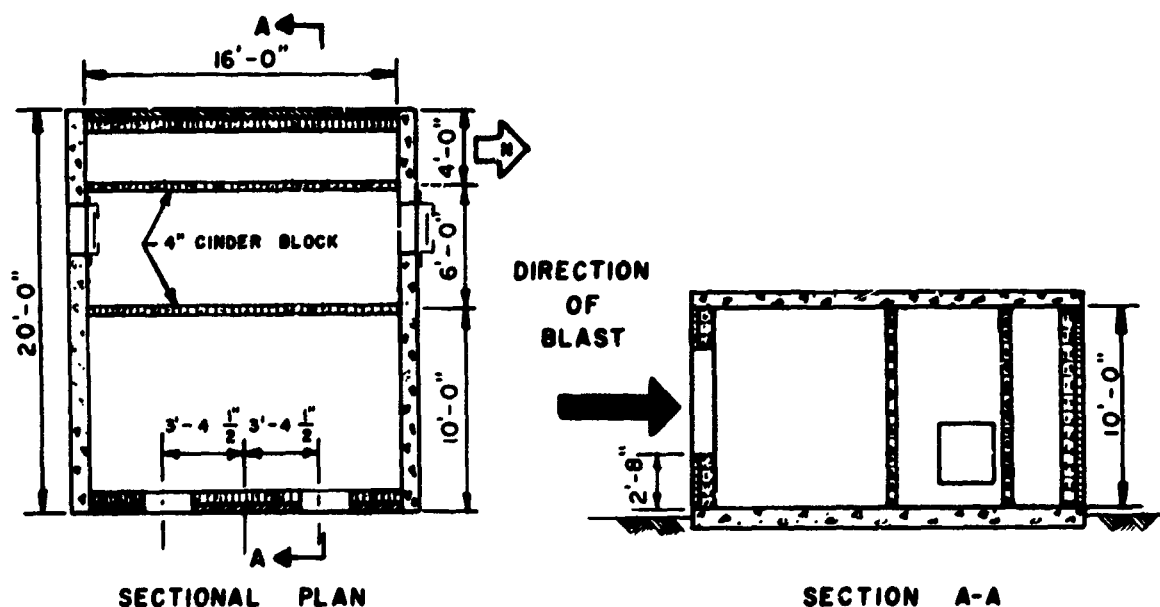
Fig. 2.86 Post Shot Photography - Cell No. 12b





Fig. 2.87 Post Shot - Interior - Cell No. 12b

# CELL NO.13b 10'x16' OPENING



## DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing and 8 in. cinder block backing. There were two windows in the front wall, 3 ft 3 in. by 5 ft 5 in. The partitions were 4 in. cinder block with 3/4 in. plaster on each face. The partitions had mortar joints at the top and bottom and dovetail anchors and mortar joints at the side edges.

## CONSTRUCTION ERRORS AND OMISSIONS:

Dovetail anchors should not have been used at the side edges of the partitions.

## FIELD DAMAGE NOTES:

The partitions were destroyed except for some fillets.

The front wall was slightly spalled at the top on the outside face.

The rear wall was spalled at the top on the outside face.

The measured, pre shot and post shot, natural frequencies of the front wall were 39.7 cps and 20.4 cps, respectively. For the rear wall, the measured, pre shot and post shot, natural frequencies were 62.5 cps and 37.1 cps, respectively.



Front Wall



Front Wall



Rear Wall



Rear Wall

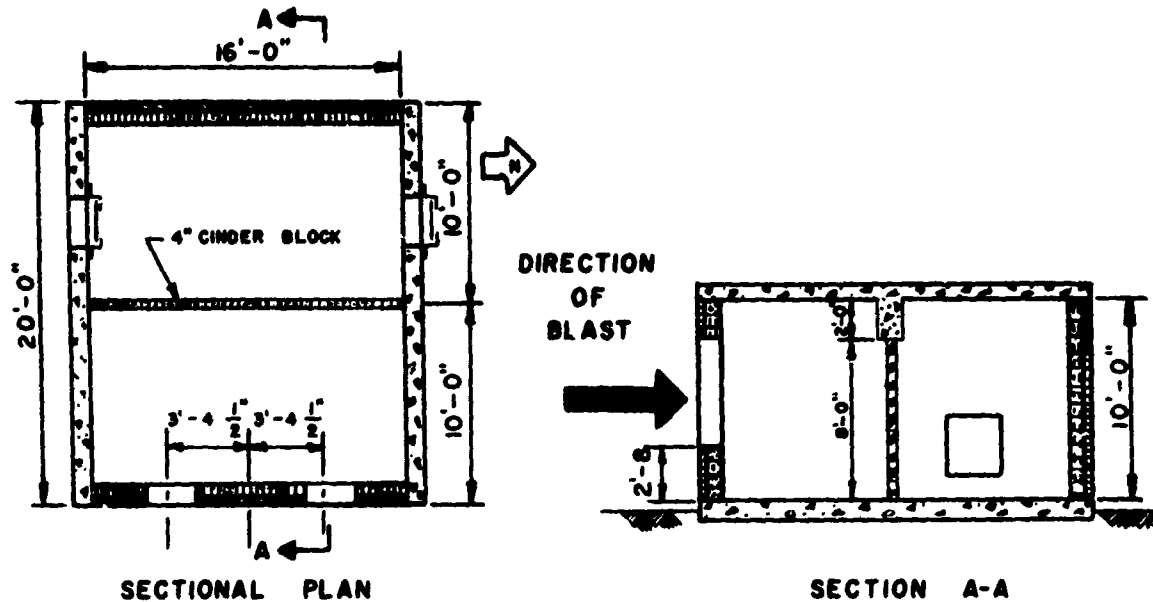
Fig. 2.88 Pre Shot Photography - Cell No. 13b

Fig. 2.89 Post Shot Photography - Cell No. 13b



Fig. 2.90 Post Shot - Interior - Cell No. 13b

# CELL NO.14b 10'x16' OPENING



## DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing and 8 in. cinder block backing. There were two windows in the front wall, 3 ft 3 in. by 5 ft 5 in. The partition was 4 in. cinder block with 3/4 in. plaster on each face. The partition had mortar joints at the top and bottom and dovetail anchors and mortar joints at the side edges.

## CONSTRUCTION ERRORS AND OMISSIONS:

None

## FIELD DAMAGE NOTES:

The partition was almost destroyed except for fillets.

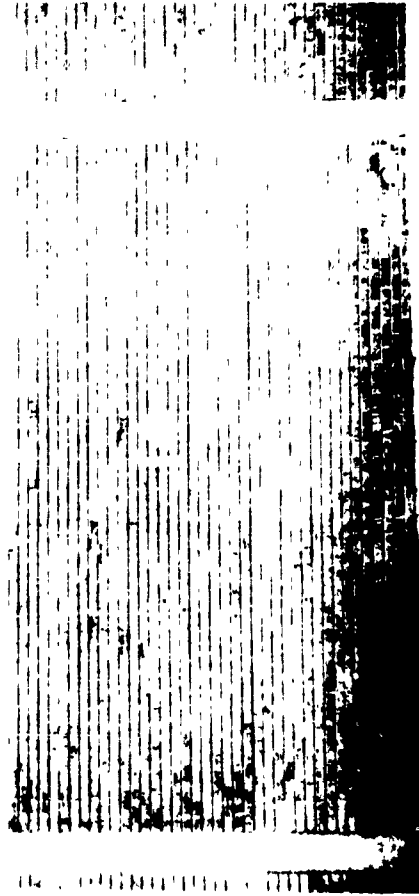
The front wall had a horizontal hair crack at the 5th joint above the sill, at the center section, on the inside face.

The rear wall was spalled at the top and bottom on the outside face.

The measured, pre shot and post shot, natural frequencies of the front wall were 37.8 cps and 23.4 cps, respectively. For the rear wall, the measured, pre shot and post shot, natural frequencies were 35.4 cps and 23.0 cps, respectively.

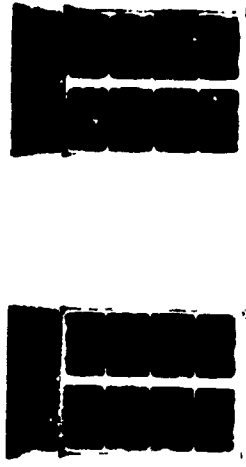


Front Wall



Rear Wall

Fig. 2.91 Pre Shot Photography - Cell No. 14b



Front Wall



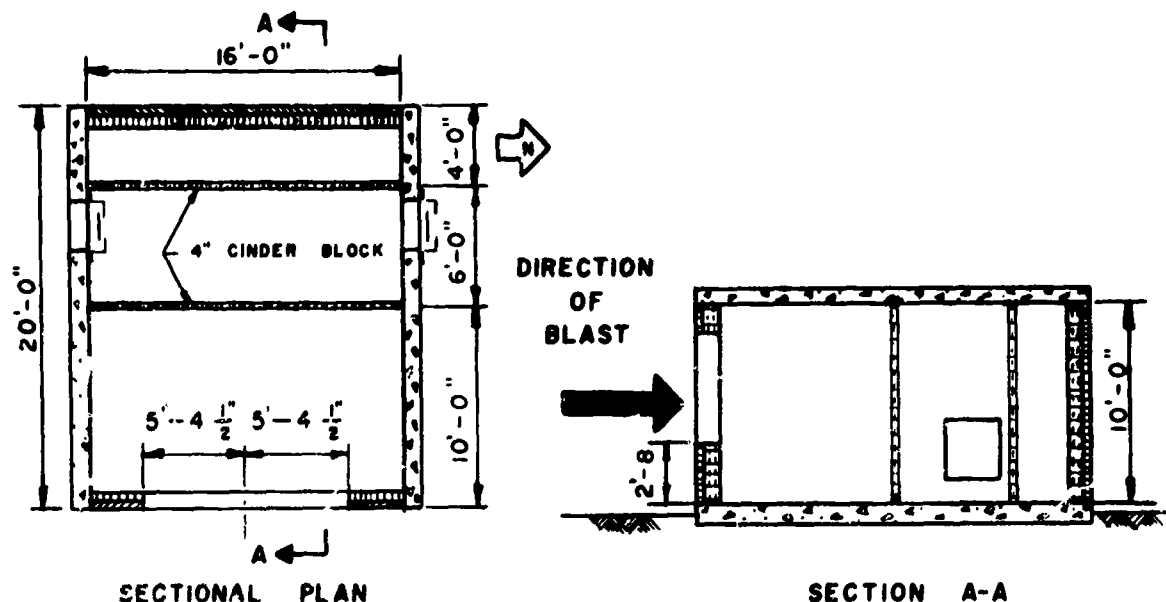
Rear Wall

Fig. 2.92 Post Shot Photography - Cell No. 14b



Fig. 2.93 Post Shot - Interior - Cell No. 14b

# CELL NO.15b 10'x16' OPENING



## DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing and 8 in. cinder block backing. There was one window in the front wall, 5 ft 5 in. by 10 ft 9 in. The partitions were 4 in. cinder block with 3/4 in. plaster on each face. The partitions had mortar joints at the top and bottom and dovetail anchors and mortar joints at the side edges.

## CONSTRUCTION ERRORS AND OMISSIONS:

None

## FIELD DAMAGE NOTES:

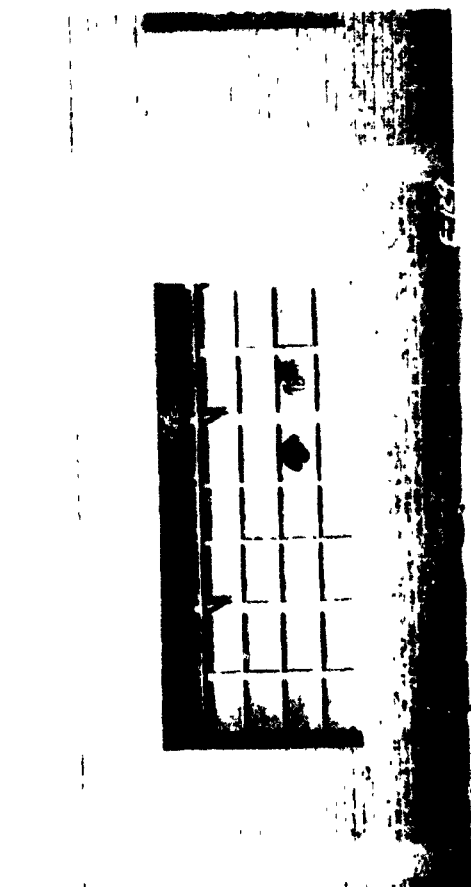
The partitions were destroyed except for fillets.

The front wall had a vertical crack in the center above the window on the inside and outside face. There was spalling at the top of the outside face. The window frame was blown loose at the top south side.

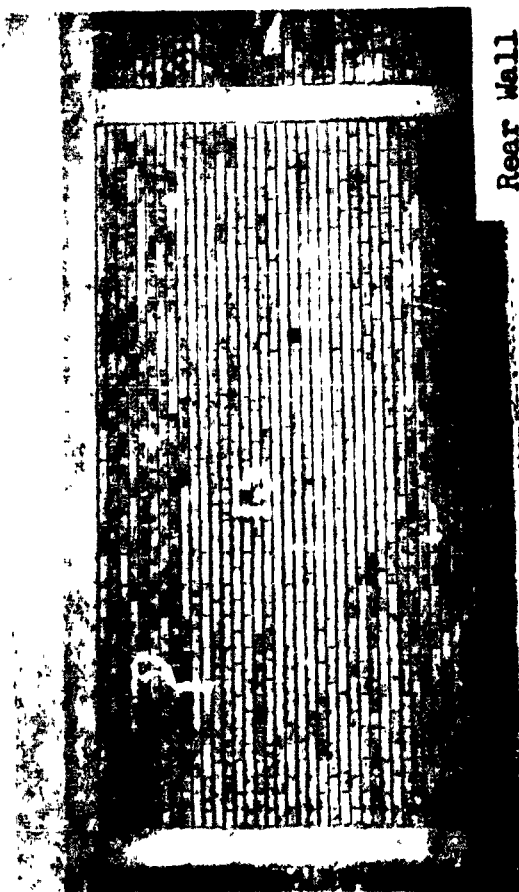
The rear wall had a vertical hair crack on the inside face from the top down to the pile of debris. The outside face was slightly spalled at the top.

The measured, pre shot and post shot, natural frequencies of the front wall were 30.9 cps and 20.9 cps, respectively. For the rear wall, the measured, pre shot and post shot, natural frequencies were 45.8 cps and 22.1 cps, respectively.



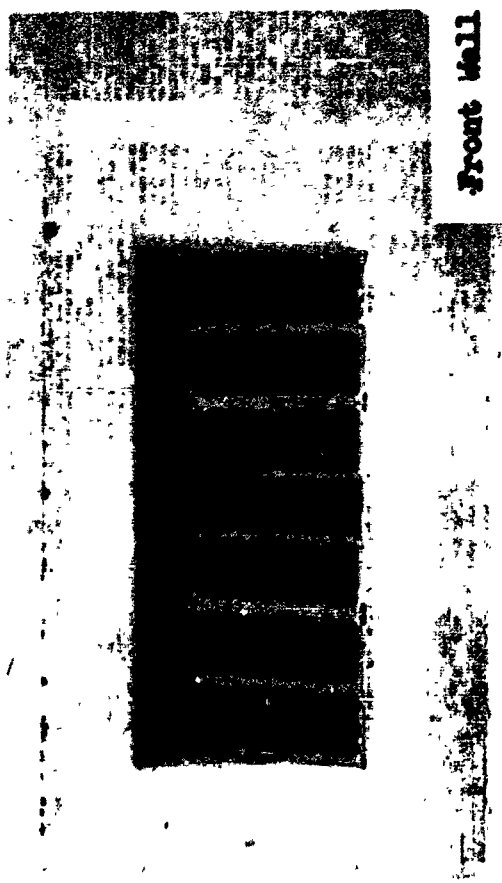


Front Wall

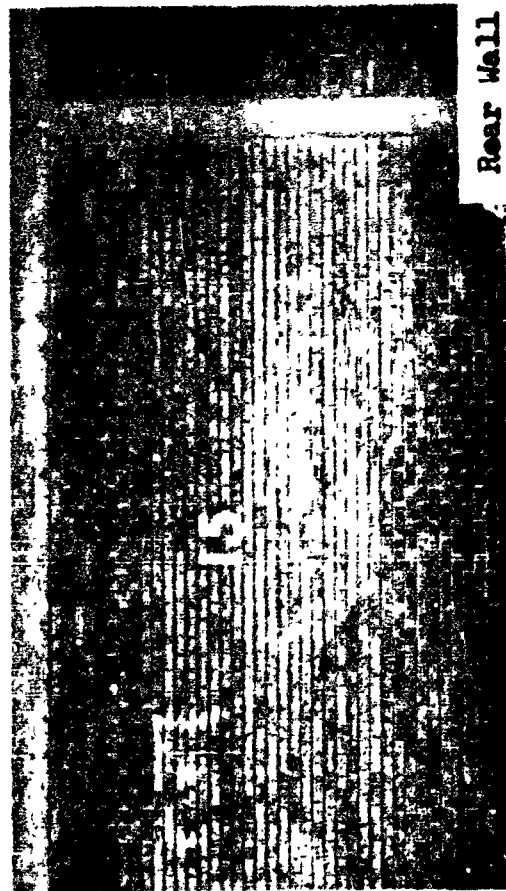


Rear Wall

Fig. 2.94 Pre Shot Photography - Cell No. 15b



Front Wall



Rear Wall

Fig. 2.95 Post Shot Photography - Cell No. 15b

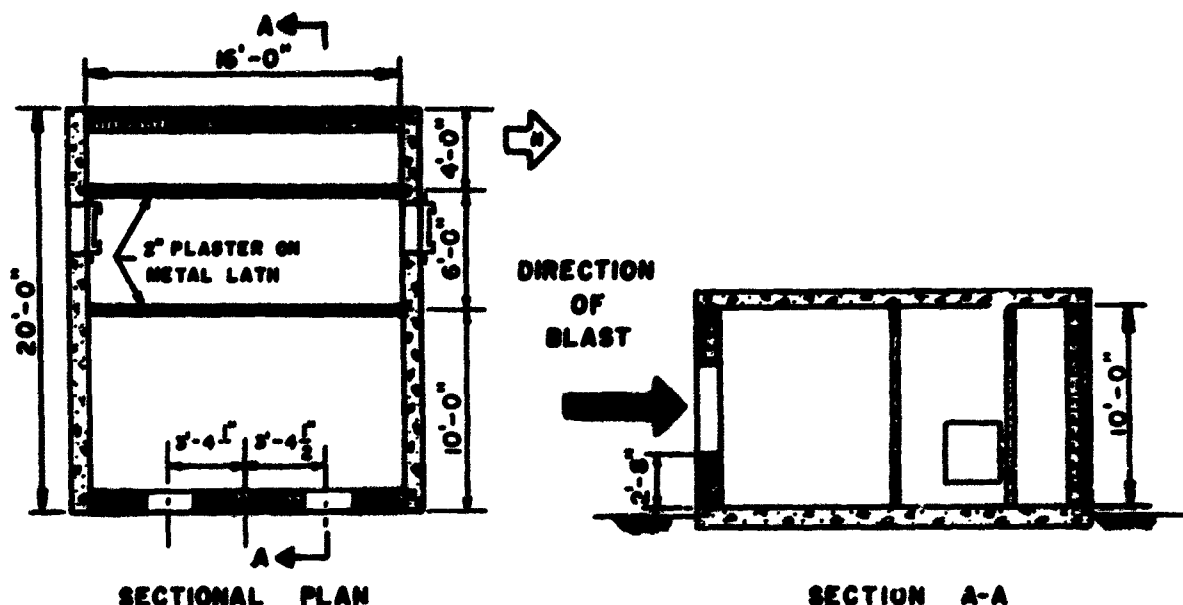


Fig. 2.96 Post Shot - Interior - Cell No. 15b



Fig. 2.97 Post Shot - Front Wall Detail  
Cell No. 15b

# CELL NO.16b 10'x16' OPENING



## DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing and 8 in. cinder block backing. There were two windows in the front wall, 3 ft 3 in. by 5 ft 5 in. The partitions were 2 in. plaster on metal lath attached to 1 in. x 1 in. x 3/16 in. angles which were secured to the floor and roof slabs with 3/8 in. round expansion bolts at 2 ft on centers.

## CONSTRUCTION ERRORS AND OMISSIONS:

The 1 in. x 1 in. x 3/16 in. angles at the side edges of the partitions were not installed.

## FIELD DAMAGE NOTES:

The partitions were blown against the rear wall and badly broken.

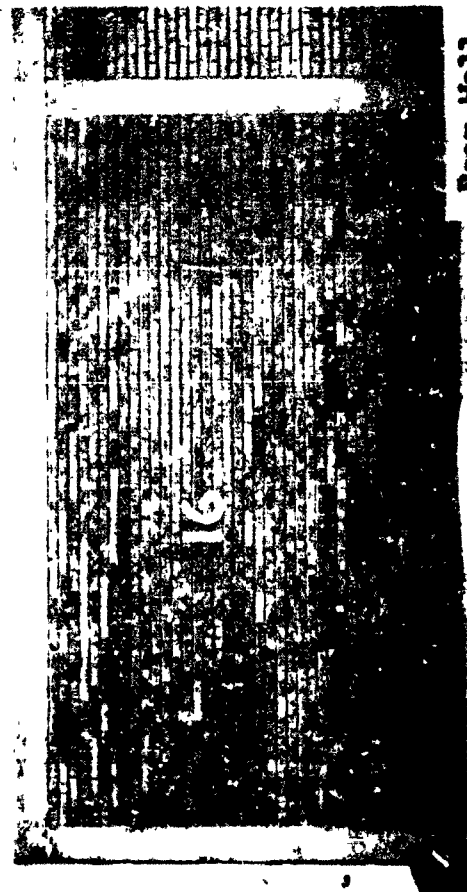
The front wall was cracked at the center section of the inside face, at the 2nd cinder block joint above the sill line. The outside face was spalled at the top. The window frames were bowed in.

The rear wall was bowed out 1/2 in. at the top center with a vertical crack half way down the wall.

The measured, pre shot and post shot, natural frequencies of the front wall were 33.0 cps and 39.1 cps, respectively. For the rear wall, the measured, pre shot and post shot, natural frequencies were 47.7 cps and 17.7 cps, respectively.

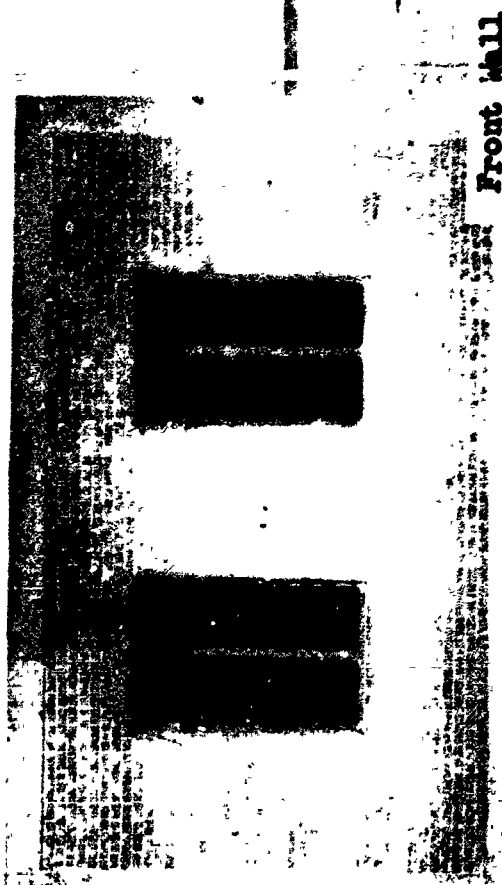


Front Wall

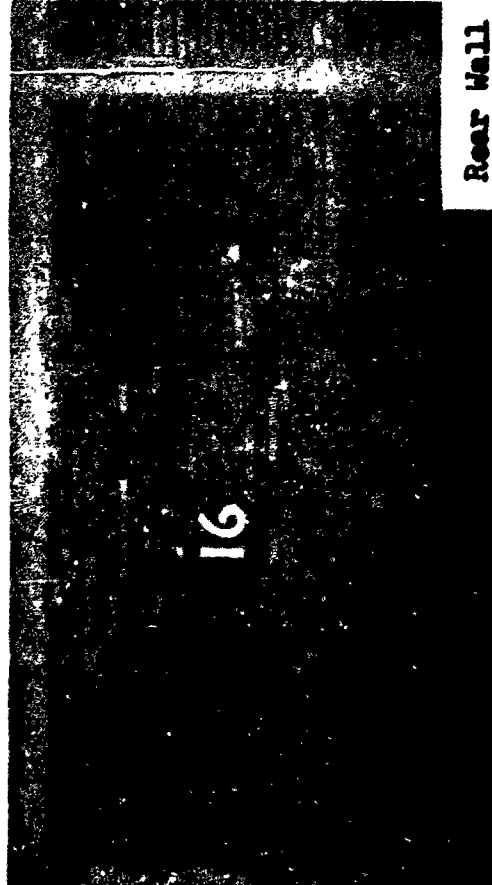


Rear Wall

Fig. 2.98 Pre Shot Photography - Cell No. 16b



Front Wall



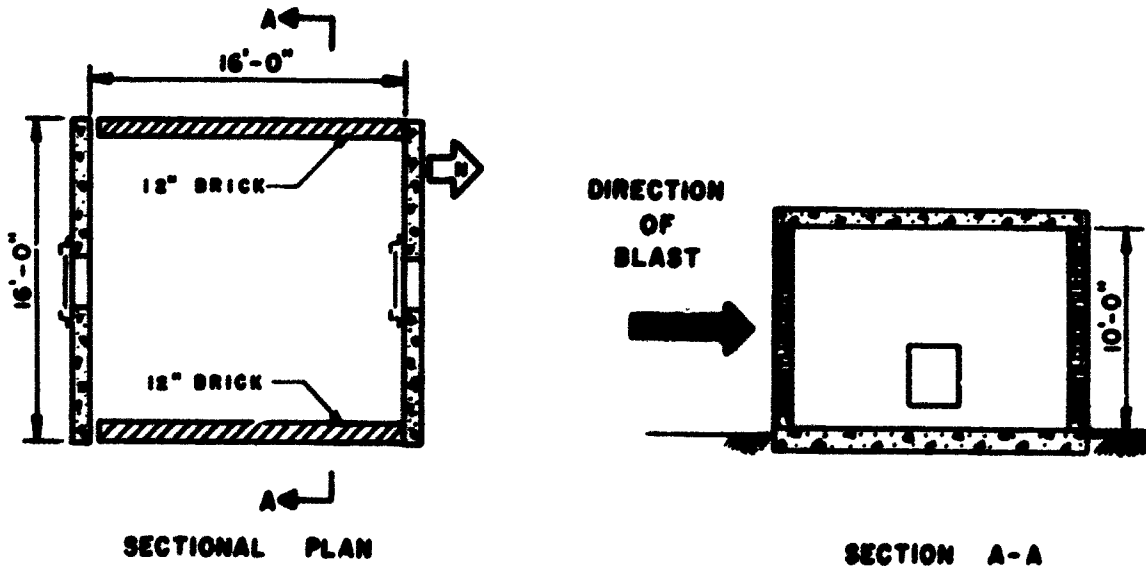
Rear Wall

Fig. 2.99 Post Shot Photography - Cell No. 16b



Fig. 2.100 Post Shot - Interior - Cell No. 16b

### CELL NO. 1c 10'x16' OPENING



#### DESCRIPTION:

The front and rear walls consisted of 12 in. solid brick with headers placed every 7th course and mortar joints at the top and bottom. The south edge had an angle extending from the bottom of the roof slab to the top of the floor slab, for a fibre glass cloth blast closure of the joint. The north edge had dovetail anchors and a mortar joint.

#### CONSTRUCTION ERRORS AND OMISSIONS:

The angle at the south edge, holding the fibre glass cloth, should not have extended above the bottom of the roof slab or below the top of the floor slab.

#### FIELD DAMAGE NOTES:

The front wall was blown in with the south section rotating about the angle support and the north section rotating a lesser amount.

The rear wall was spalled, at the top, on the outside face.

The measured, pre shot, natural frequency of the front wall was 37.5 cps. For the rear wall, the measured pre shot and post shot, natural frequencies were 56.1 cps and 47.6 cps, respectively.



Front Wall



Rear Wall

Fig. 2.101 Pre Shot Photography - Cell No. 1c



Front Wall



Rear Wall

Fig. 2.102 Post Shot Photography - Cell No. 1c

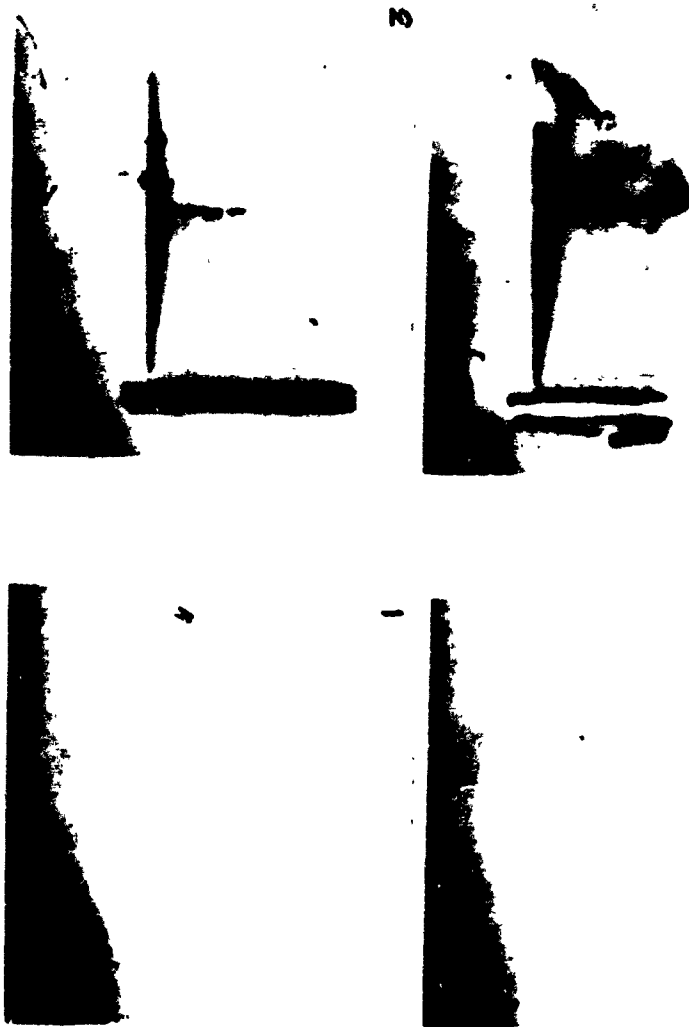


Fig. 2.103 Motion Picture Sequence - Front Wall - Cell No. 1c





Fig 2.104 Post Shot - Interior - Front Wall  
Cell No. 1c

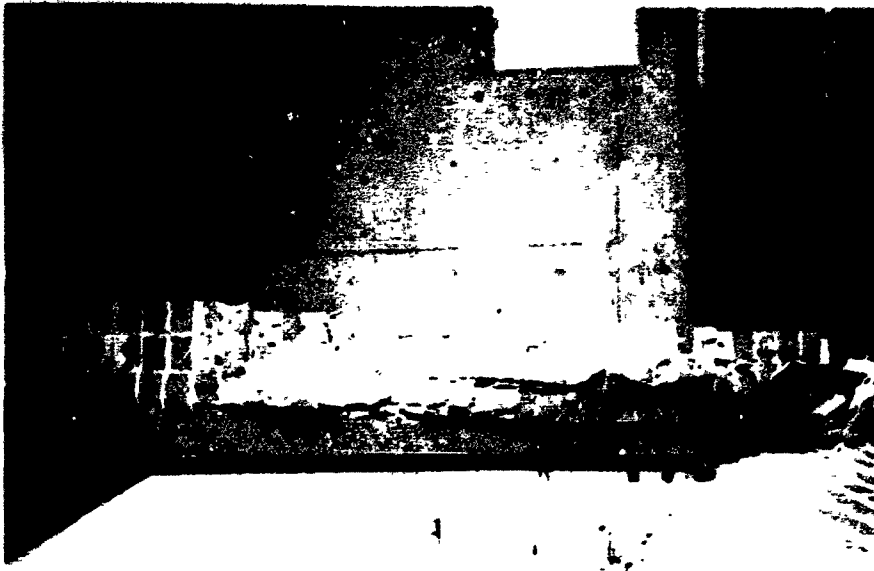


Fig 2.105 Post Shot - Front Wall Detail  
Cell No. 1c

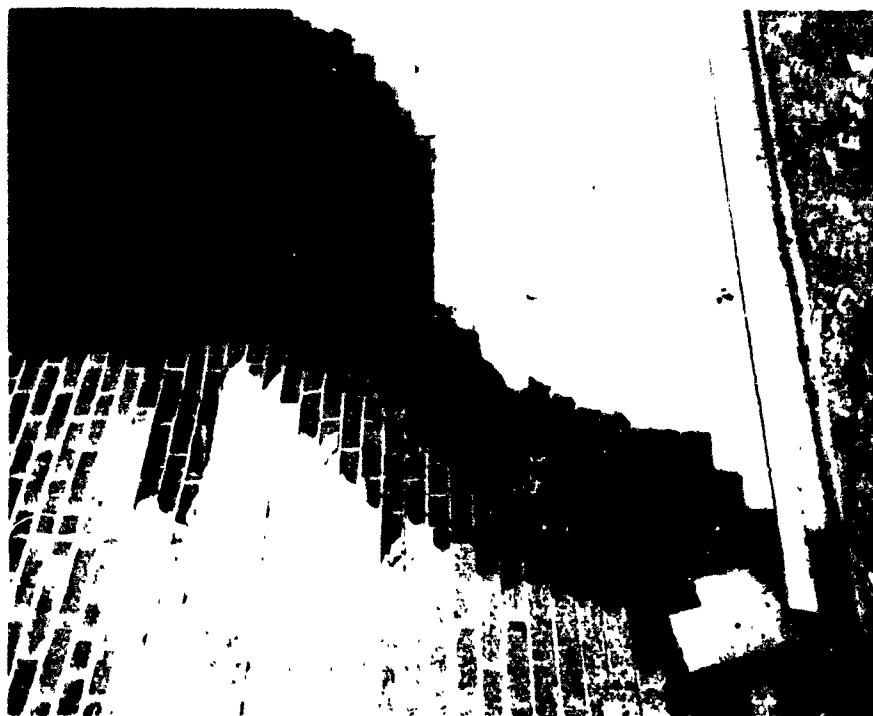
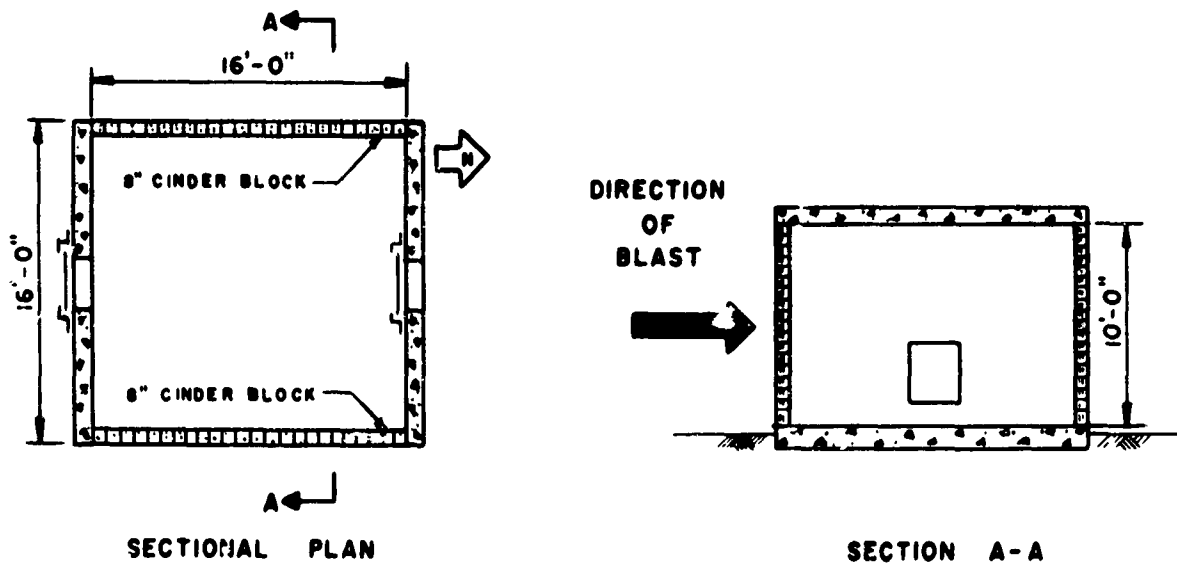


Fig. 2.106 Post Shot - Front Wall Detail  
Cell No. 1c



Fig. 2.107 Post Shot - Interior  
Cell No. 1c

### CELL NO. 2c 10'x16' OPENING



#### DESCRIPTION.

The front and rear walls consisted of 8 in. cinder block with mortar joints at the top and bottom and dovetail anchors and mortar joints at the side edges.

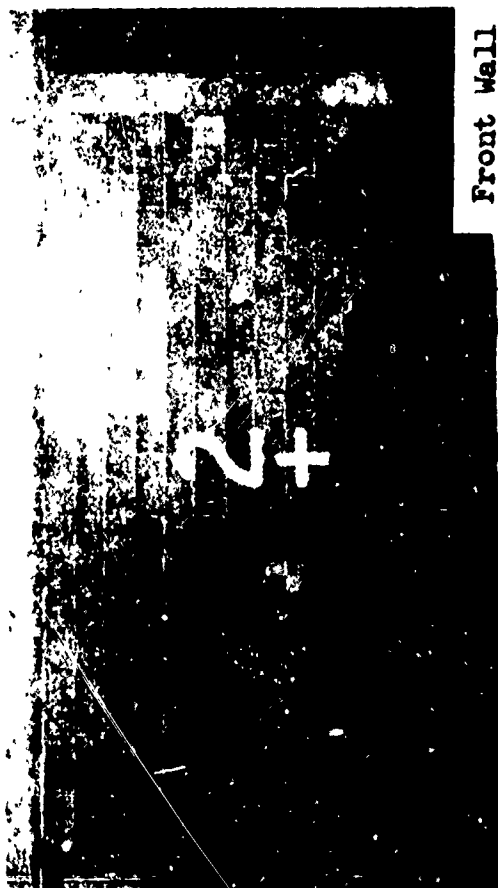
#### CONSTRUCTION ERRORS AND OMISSIONS:

Square end, two cell blocks were used instead of the three cell type.

#### FIELD DAMAGE NOTES:

The front and rear walls were blown through the rear of the cell. Rubble from the walls was found 60 feet to the rear of the structure.

The measured, pre shot, natural frequencies of the front and rear walls were 68.8 cps and 34.7 cps, respectively.



Front Wall

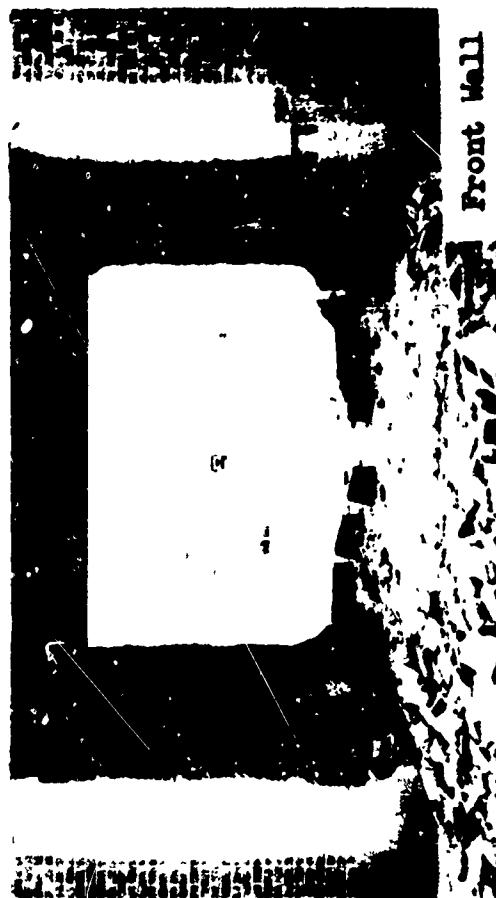


Front Wall

Fig. 2.108 Pre Shot Photography - Cell No. 2c



Front Wall



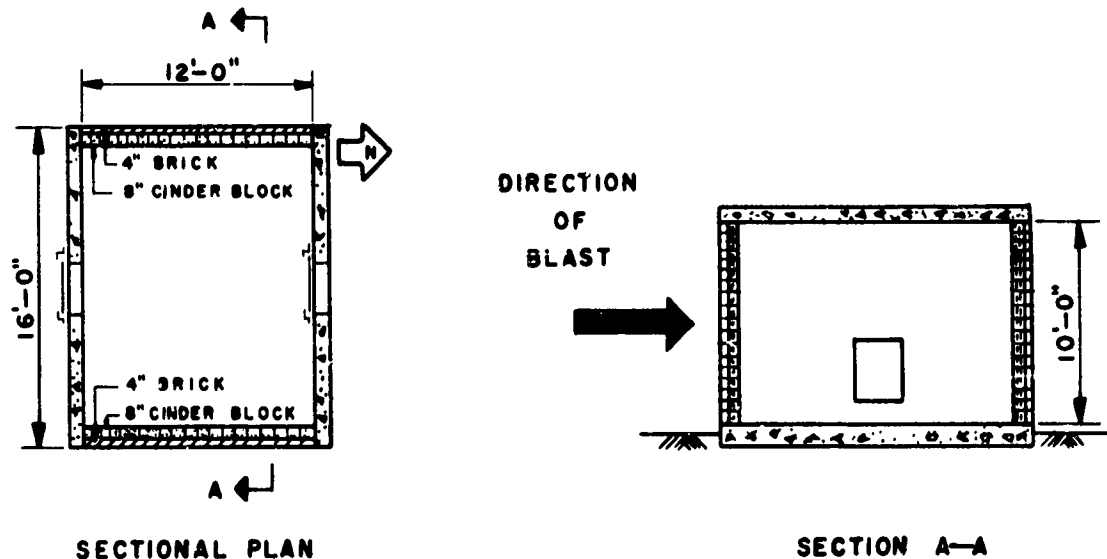
Front Wall

Fig. 2.109 Post Shot Photography - Cell No. 2c



Fig. 2.110 Motion Picture Sequence - Front Wall - Cell No. 2c

# CELL NO. 3c 10'x12' OPENING



## DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing with 8 in. cinder block backing. Standard brick ties were placed every 6th course and at 4 ft on centers with mortar joints at the top and bottom and dovetail anchors and mortar joints at the side edges.

## CONSTRUCTION ERRORS AND OMISSIONS:

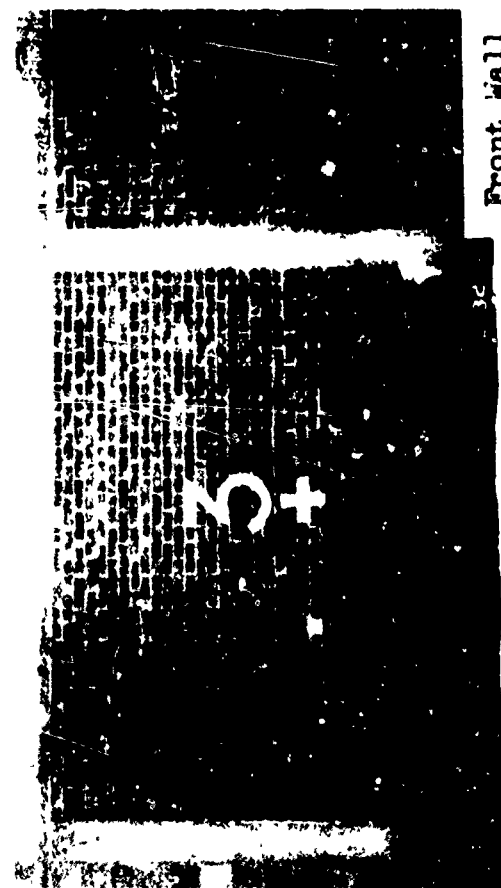
None

## FIELD DAMAGE NOTES:

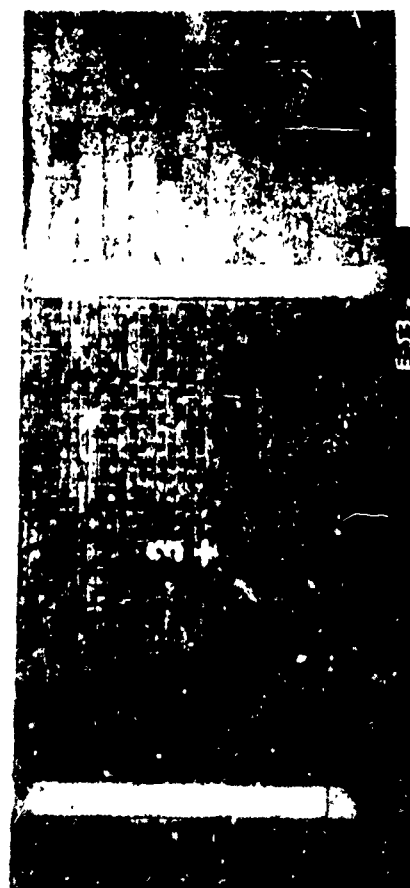
The front wall was blown into the cell, except for about 1 ft on the side edges, top to bottom, and 3 courses at the bottom.

The rear wall was slightly spalled, at the top and the north edge, on the outside face.

The measured, pre shot, natural frequency of the front wall was 41.7 cps. For the rear wall, the measured pre shot and post shot, natural frequencies were 40.3 cps and 36.1 cps, respectively.



Front Wall



Rear Wall



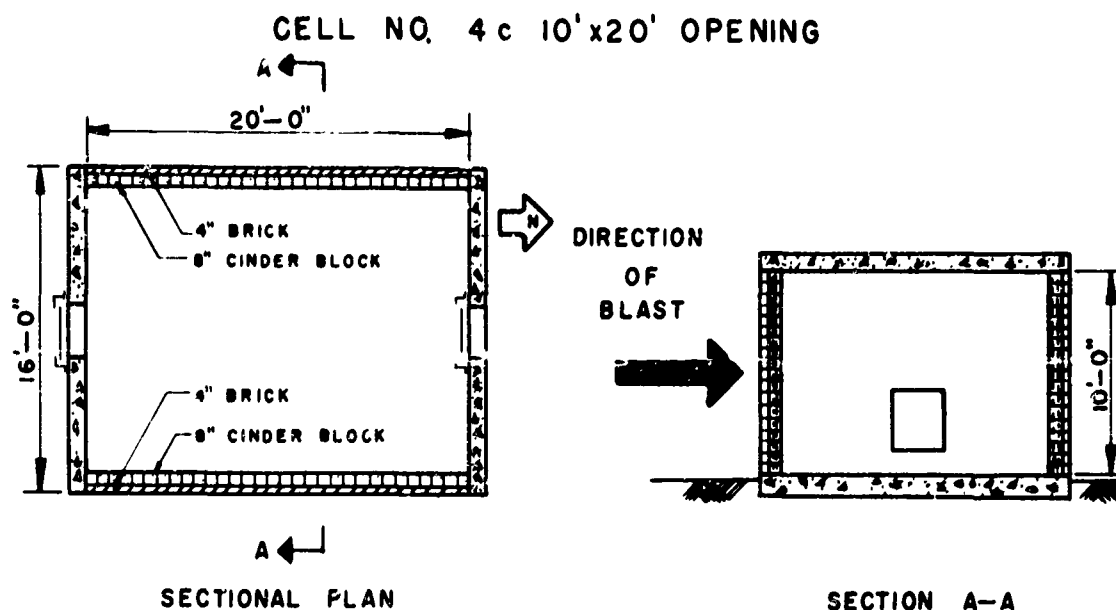
Front Wall



Rear Wall

Fig. 2.111 Pre Shot Photography - Cell No. 3c

Fig. 2.112 Post Shot Photography - Cell No. 3c



#### DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing with 8 in. cinder block backing. Standard brick ties were placed every 6th course and at 4 ft on centers with mortar joints at the top and bottom and dovetail anchors and mortar joints at the side edges.

#### CONSTRUCTION ERRORS AND OMISSIONS:

None

#### FIELD DAMAGE NOTES

The front wall was blown into the cell except for 1 ft at the side edges and 3 courses at the bottom.

The rear wall was cracked down the middle of the outside face and bowed out 3 in. to 4 in. at the top center and 1 in. to 2 in. at the bottom center. The south edge and lower half of the north edge were in place; the upper half of the north edge pushed out up to 1 in. The inside face was bowed out at the center and was cracked vertically near the side edges with several holes punched in the block cells.

The measured, pre shot, natural frequency of the front wall was 26.5 cps. For the rear wall, the measured, pre shot and post shot, natural frequencies were 31.2 cps and 36.3 cps, respectively.



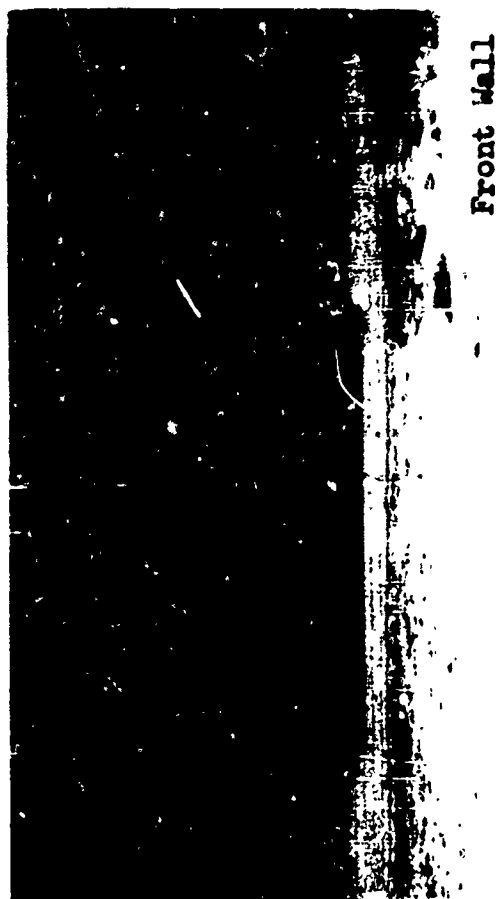


Fig. 2.114 Post Shot Photography - Cell No. 4c

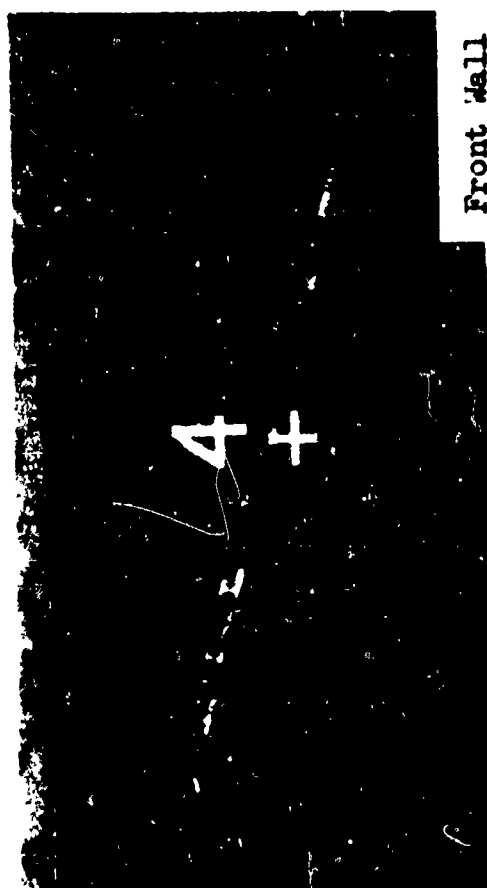
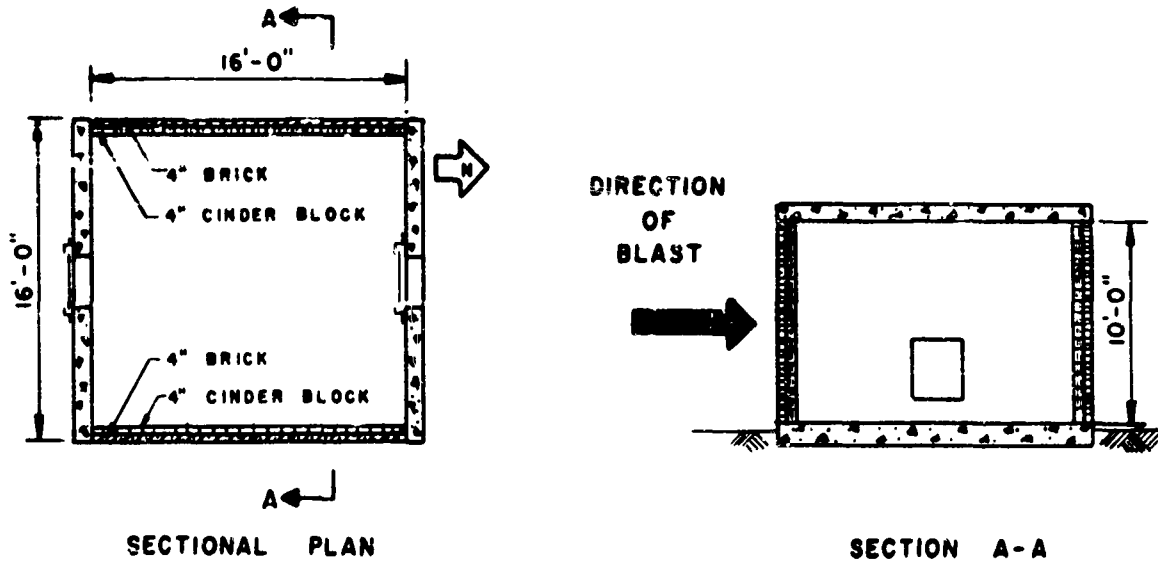


Fig. 2.113 Pre Shot Photography - Cell No. 4c

### CELL NO. 5c 10'x16' OPENING



#### DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing with 4 in. cinder block backing. Standard brick ties were placed every 6th course and at 4 ft on centers with mortar joints at the top and bottom with an angle bearing on the inside. The side edges had dovetail anchors and mortar joints.

#### CONSTRUCTION ERRORS AND OMISSIONS:

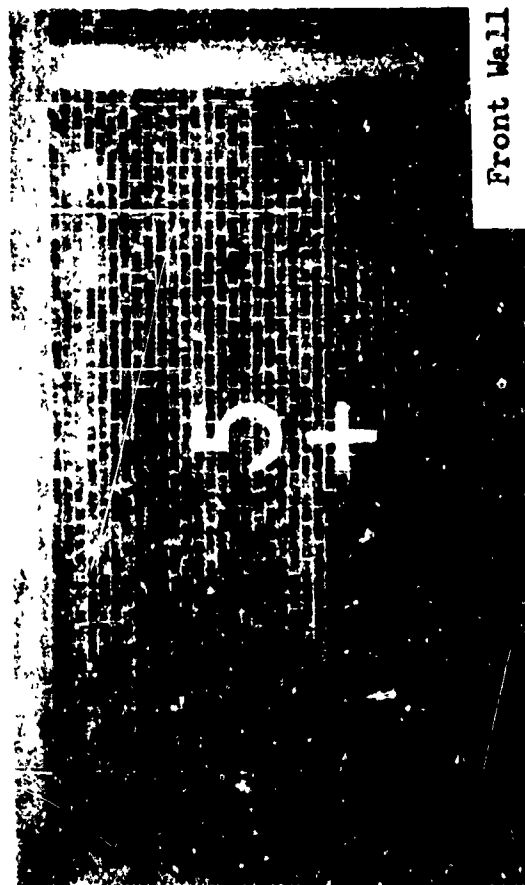
None

#### FIELD DAMAGE NOTES:

The front wall was blown into the cell except for 3 courses at the bottom and the bottom corner fillets.

The rear wall was spalled at the top and bottom of the outside face and bowed out at the top center about 1 in. with a vertical crack halfway down the middle. The outside face was also spalled at the lower north end. The inside face had minor missile damage.

The measured, pre shot and post shot, natural frequencies of the rear wall were 25.1 cps and 5.3 cps, respectively. For the front wall, the measured, pre shot, natural frequency was 23.2 cps.



Front Wall



Rear Wall



Front Wall



Rear Wall

Fig. 2.115 Pre Shot Photography - Cell No. 5c

Fig. 2.116 Post Shot Photography - Cell No. 5c

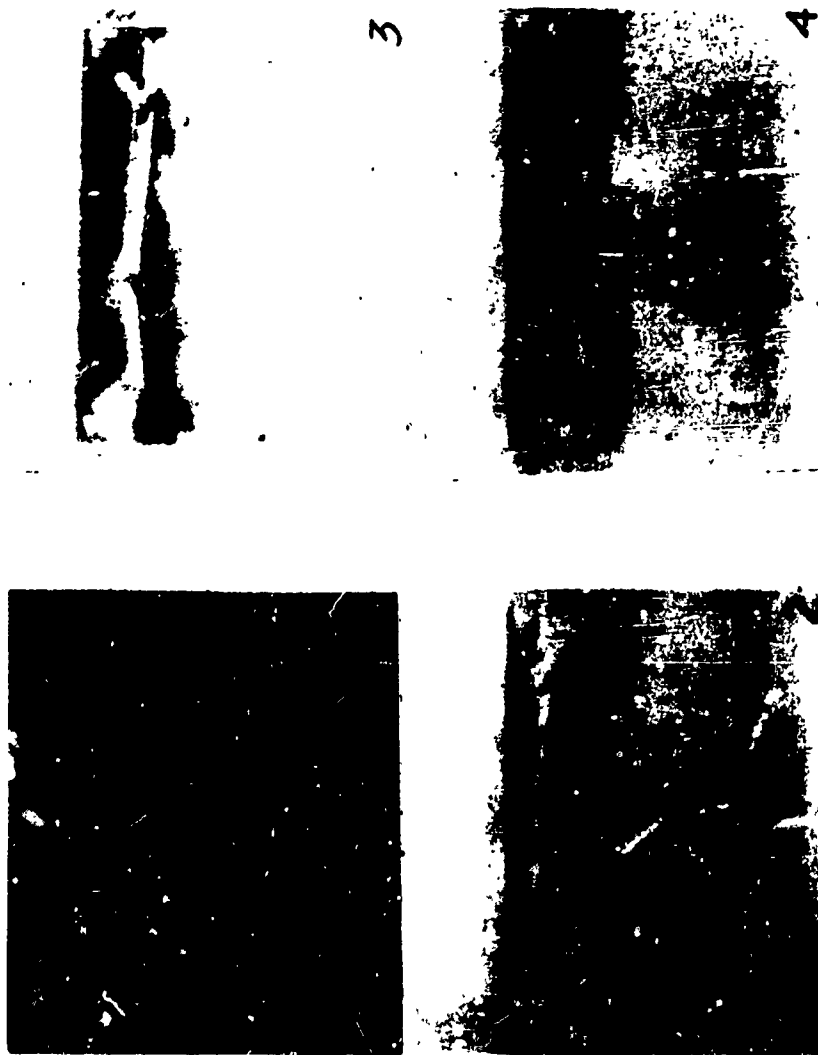
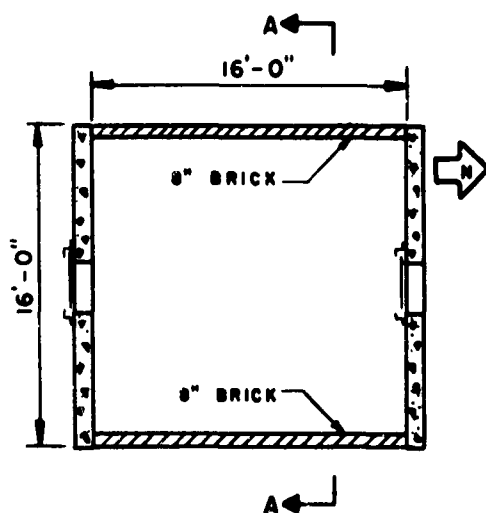


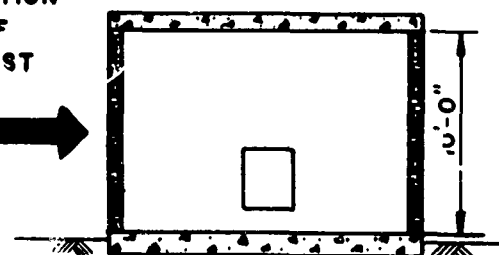
Fig. 2.117 Motion Picture Sequence - Front Wall - Cell No. 5c

# CELL NO. 6c 10'x16' OPENING



SECTIONAL PLAN

DIRECTION  
OF  
BLAST



SECTION A-A

## DESCRIPTION.

The front and rear walls consisted of 8 in. solid brick with headers placed every 7th course and mortar joints at the top and bottom. The side edges had dovetail anchors and mortar joints.

## CONSTRUCTION ERRORS AND OMISSIONS:

There was poor bond between the front wall and floor slab.

## FIELD DAMAGE NOTES:

The front wall was 85 percent blown into the cell.

The rear wall was spalled, at the top, on the outside face and was missile marked on the inside face.

The measured, pre shot, natural frequencies of the front and rear walls were 30.4 cps and 32.2 cps, respectively. The measured, post shot, natural frequency of the rear wall was 41.6 cps.

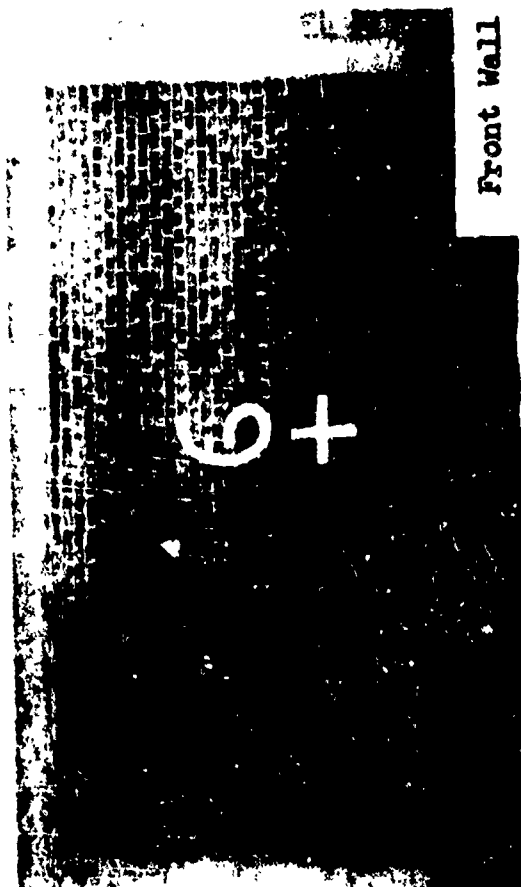


Fig. 2.118 Pre Shot Photography - Cell No. 6c

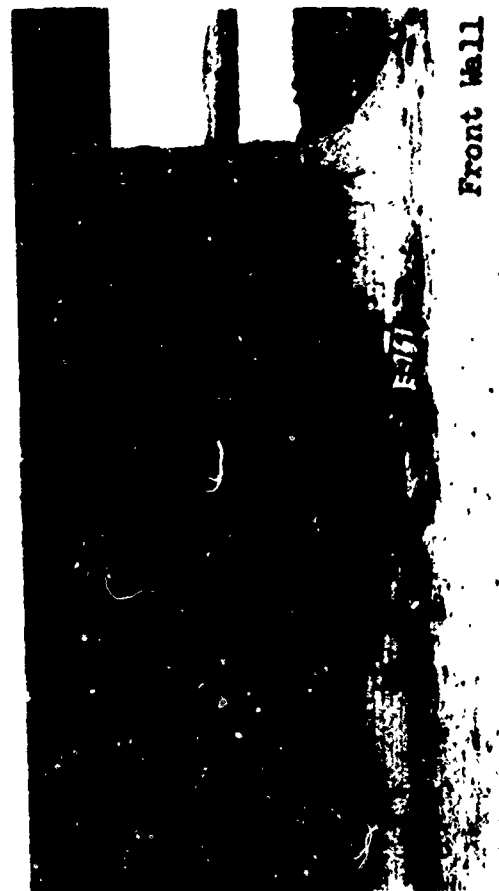


Fig. 2.119 Post Shot Photography - Cell No. 6c

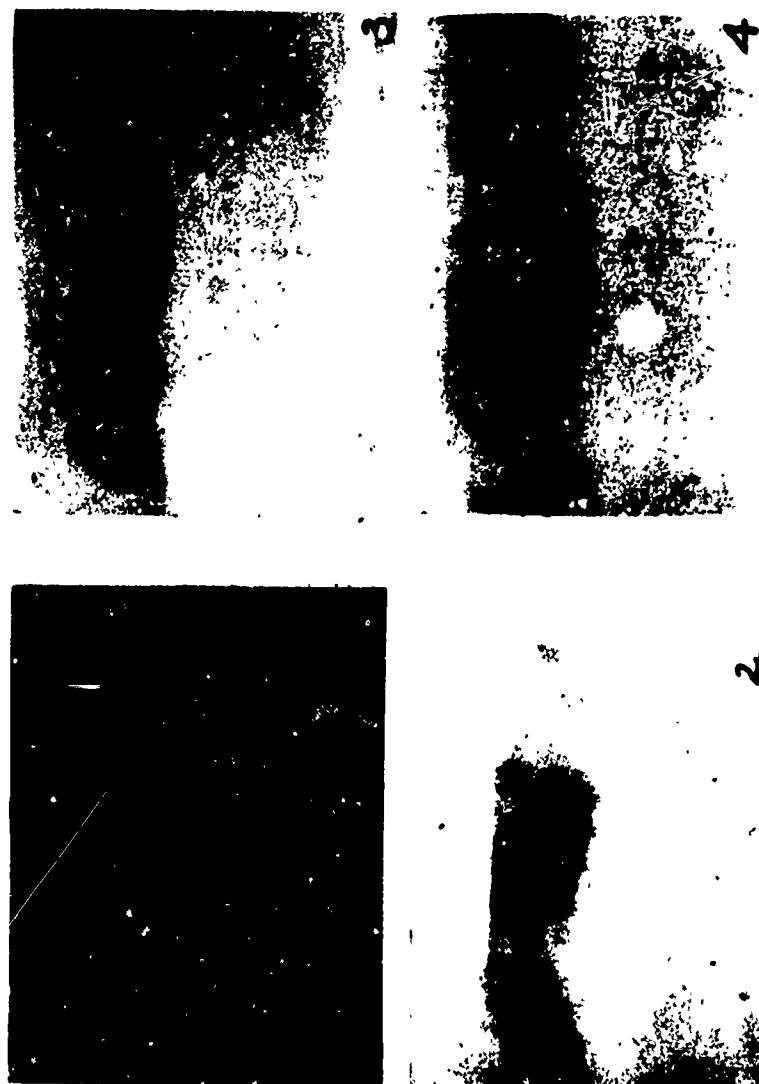


Fig. 2.120 Motion Picture Sequence - Front Wall - Cell No. 6c

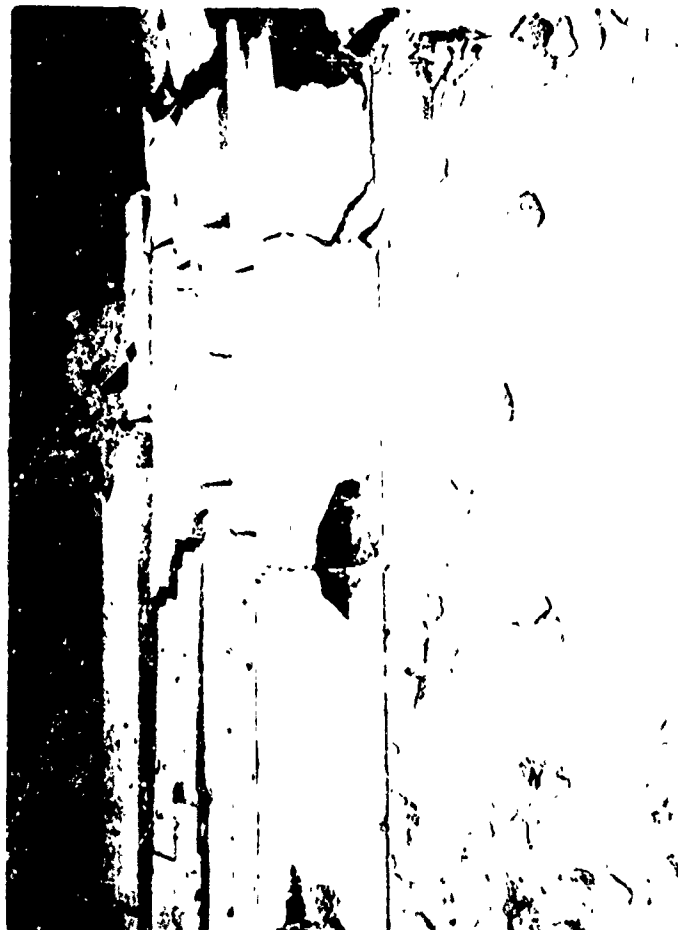


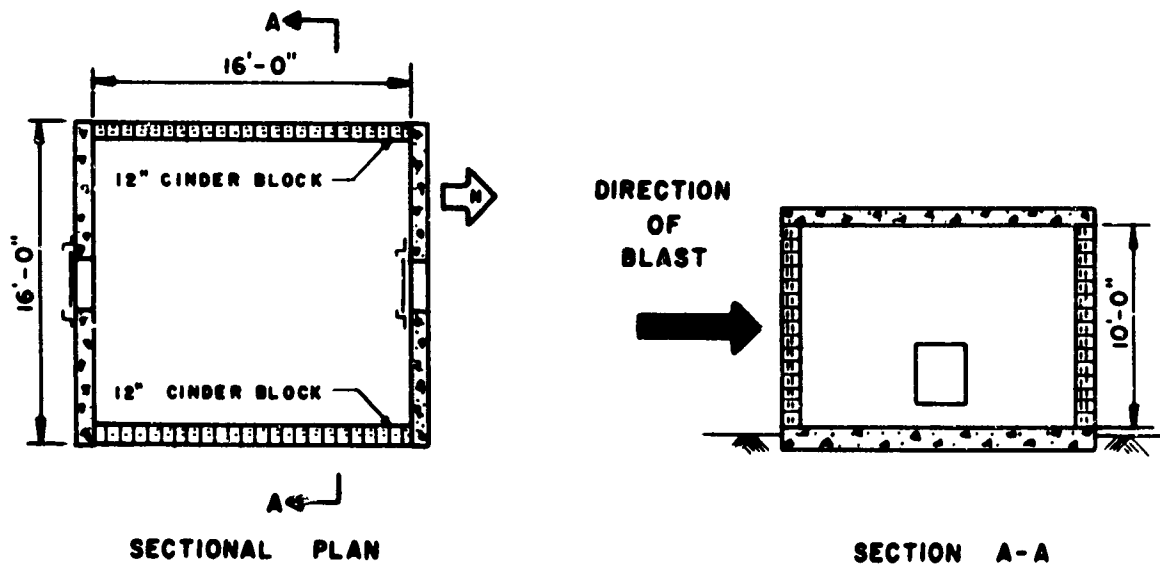
Fig. 2.121 Post Shot - Front Wall Detail  
Cell No. 6c



Fig. 2.122 Post Shot - Interior-- Front Wall  
Cell No. 6c



# CELL NO. 7c 10'x16' OPENING



## DESCRIPTION.

The front and rear walls consisted of 12 in. cinder block with mortar joints at the top and bottom. The side edges had dovetail anchors and mortar joints.

## CONSTRUCTION ERRORS AND OMISSIONS:

None

## FIELD DAMAGE NOTES:

The front wall was blown into and thru the cell except for 1 ft at the side edges.

The rear wall was 80 percent blown into the rear yard. Most of the debris from both walls was in the rear yard with rubble of block size as a maximum.

The measured, pre shot, natural frequencies of the front and rear walls were 45.8 cps and 43.5 cps, respectively.

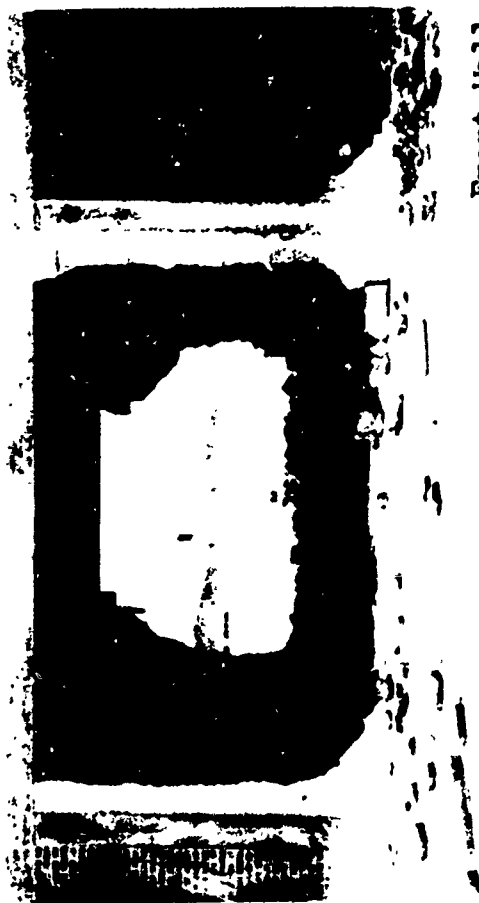


Front Wall

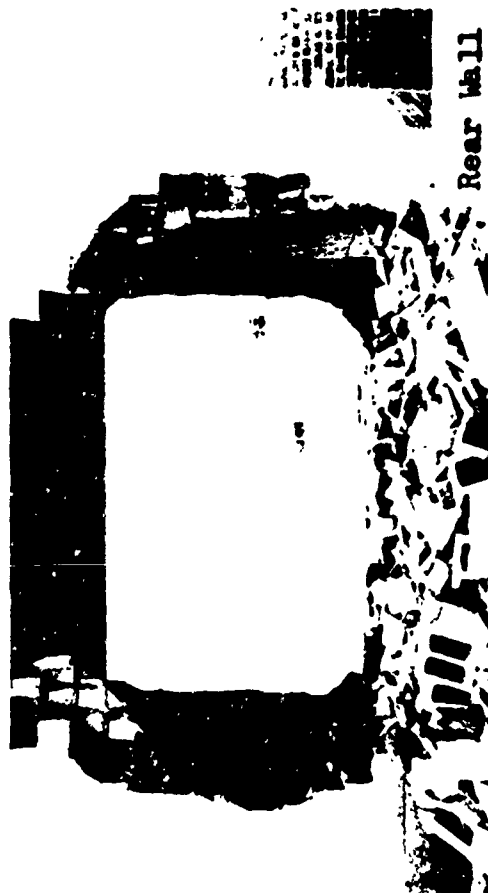


Rear Wall

Fig. 2.123 Pre Shot Photography - Cell No. 7c



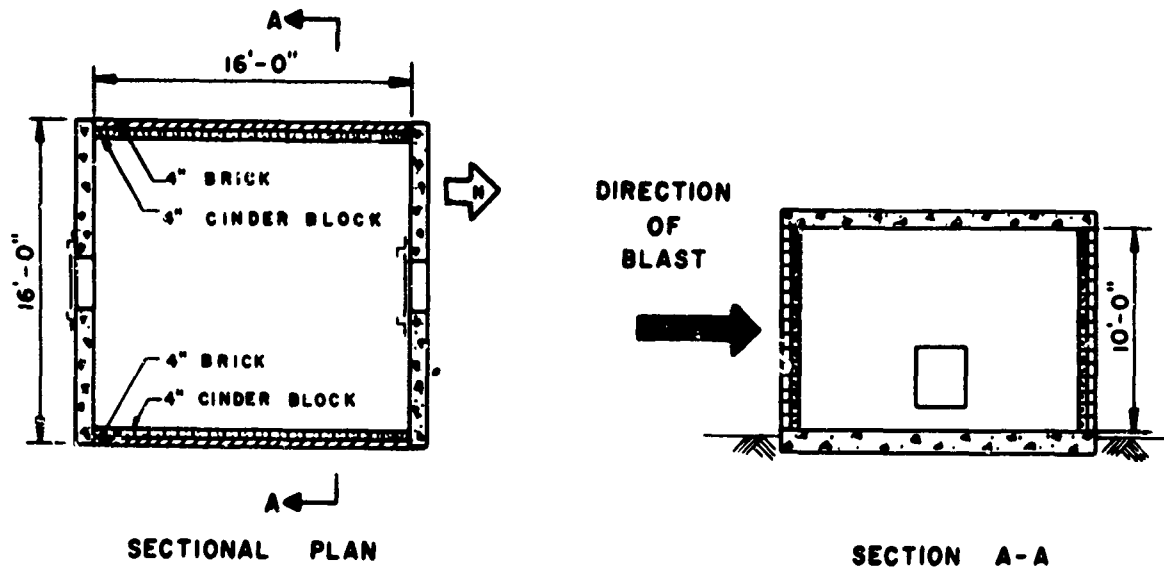
Front Wall



Rear Wall

Fig. 2.124 Post Shot Photography - Cell No. 7c

# CELL NO. 8c 10'x16' OPENING



## DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing with 4 in. cinder block backing. Standard brick ties were placed every 6th course and at 4 ft on centers with mortar joints at the top and bottom and dovetail anchors and mortar joints at the side edges.

## CONSTRUCTION ERRORS AND OMISSIONS:

None

## FIELD DAMAGE NOTES:

The front wall was 98 percent blown into the back of the cell.

The rear wall was cracked, broken, and punched outward by the debris but no openings were made thru it. The wall was punched outward up to 1 ft and was on the verge of blowing thru.

The measured, pre shot, natural frequency of the front wall was 22.7 cps. For the rear wall, the measured, pre shot and post shot, natural frequencies were 27.6 cps and 15.6 cps, respectively.

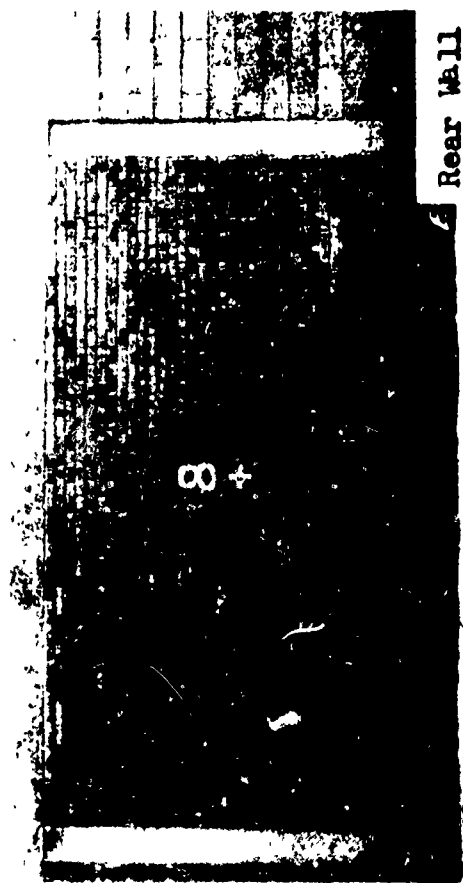
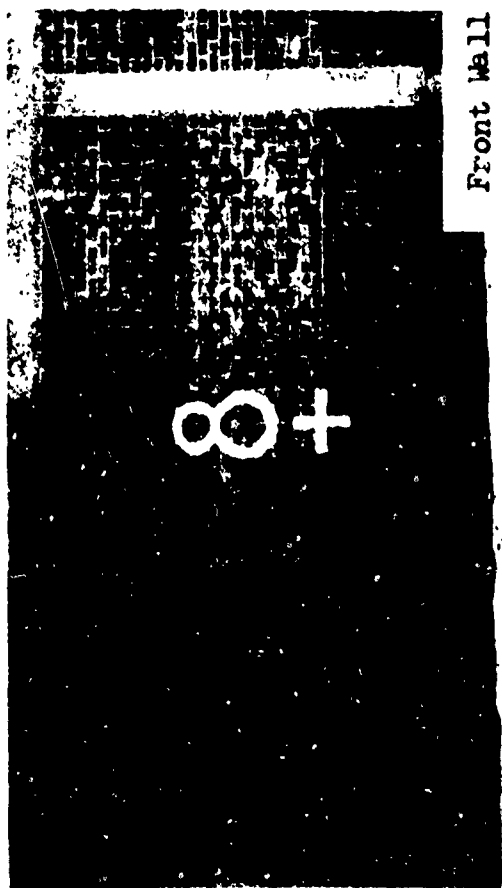


Fig. 2.125 Pre Shot Photography - Cell No. 8c

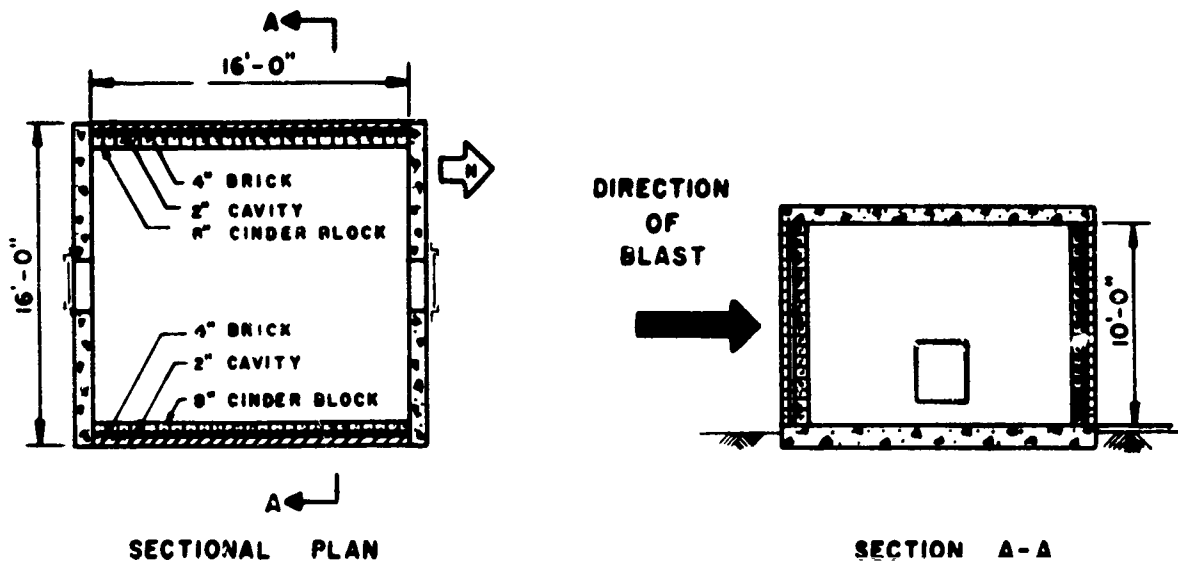


Fig. 2.126 Post Shot Photography - Cell No. 8c



Fig. 2.127 Post Shot - Rear Wall Detail - Cell No. 8c

# CELL NO. 9c 10'x16' OPENING



## DESCRIPTION.

The front and rear walls consisted of 4 in. brick facing, 2 in. cavity, and 8 in. cinder block backing. Z shaped brick ties were placed every 6th course and at 4 ft on centers with mortar joints at the top and bottom and dovetail anchors and mortar joints at the side edges.

## CONSTRUCTION ERRORS AND OMISSIONS:

None

## FIELD DAMAGE NOTES:

The front wall was blown into the cell except for a 10 in. border at the bottom and the side edges.

The rear wall was spalled, at the top, on the outside face and bowed in at the upper north corner area with a maximum of 1-1/2 in. at mid-height. The inside face had a vertical crack at the north 1/4 point with numerous holes punched into the block cells.

The measured, pre shot, natural frequencies of the front and rear walls were 26.6 cps and 30.6 cps, respectively.

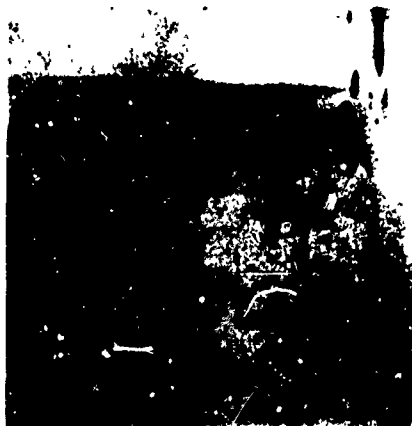
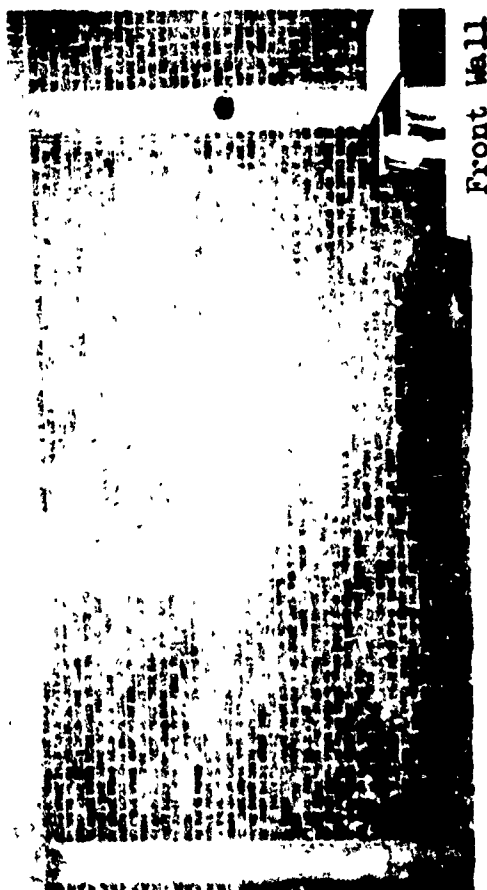


Fig. 2.130 Motion Picture Sequence - Front Wall Cell No. 9c

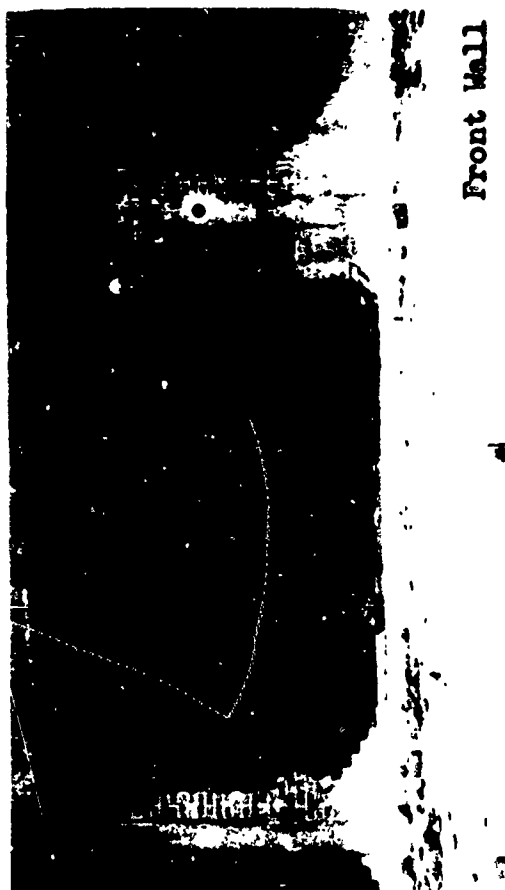


Front Wall



Rear Wall

Fig. 2.128 Pre Shot Photography - Cell No. 9c



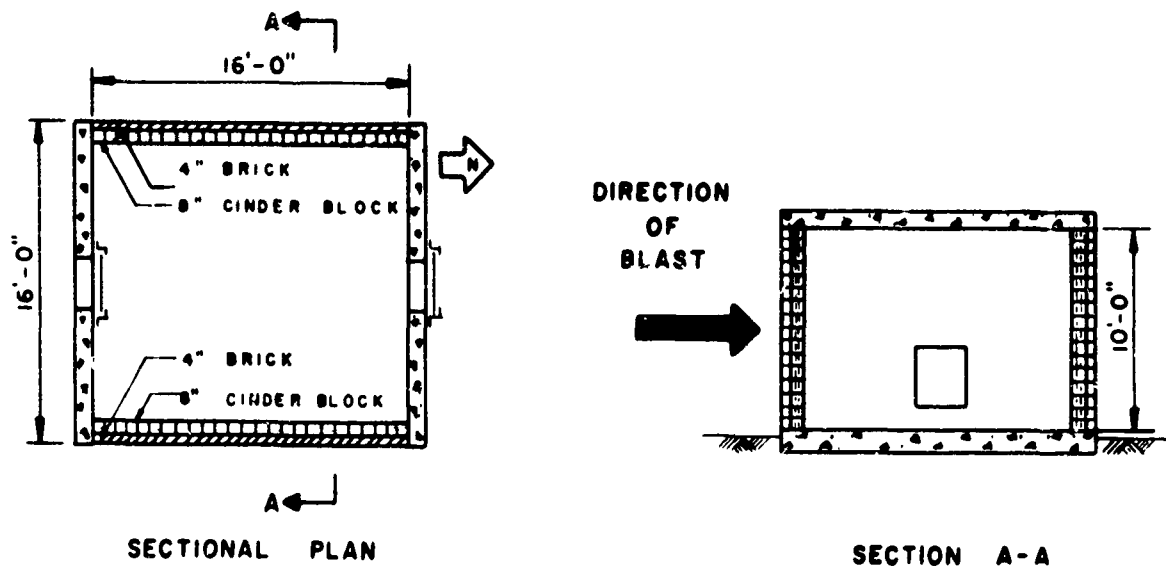
Front Wall



Rear Wall

Fig. 2.129 Post Shot Photography - Cell No. 9c

# CELL NO. 10 c 10'x16' OPENING



## DESCRIPTION

The front and rear walls consisted of 4 in. brick facing with 8 in. cinder block backing. Standard brick ties were placed every 6th course and at 4 ft on centers with mortar joints at the top and bottom and an angle bearing on the inside. The side edges had dovetail anchors and mortar joints.

## CONSTRUCTION ERRORS AND OMISSIONS:

None

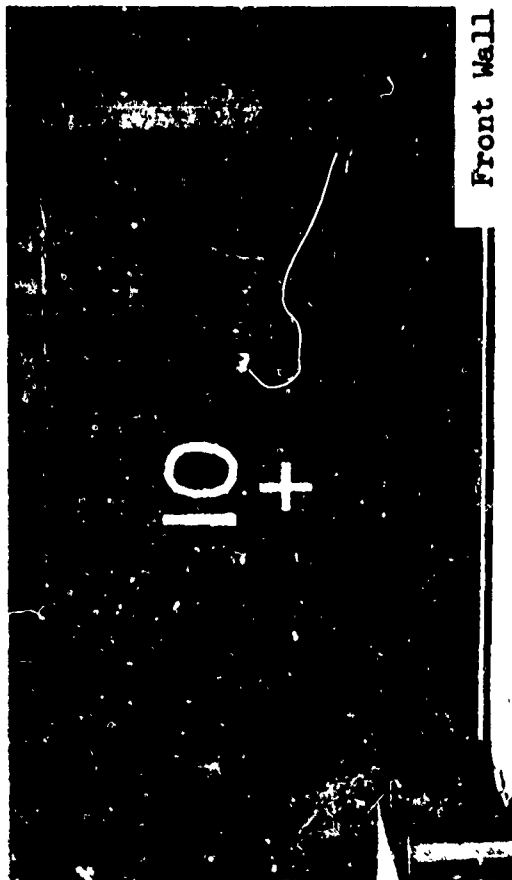
## FIELD DAMAGE NOTES:

The front wall was 75 percent blown into the back of the cell with a 1 ft border at the side edges and bottom, and 2 courses at the top remaining.

The rear wall was spalled, at the top, on the outside face. The inside face had several holes punched into the cell blocks.

The measured, pre shot, natural frequency of the front wall was 28.6 cps. For the rear wall, the measured, pre shot and post shot, natural frequencies were 41.6 cps and 25.6 cps, respectively.





Front Wall



Rear Wall

Fig. 2.131 Pre Shot Photography - Cell No. 10c



Front Wall



Rear Wall

Fig. 2.132 Post Shot Photography - Cell No. 10c

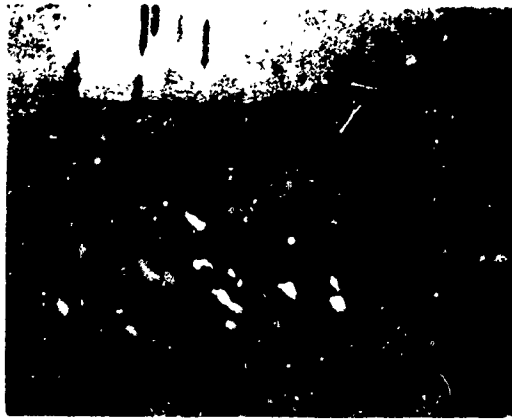
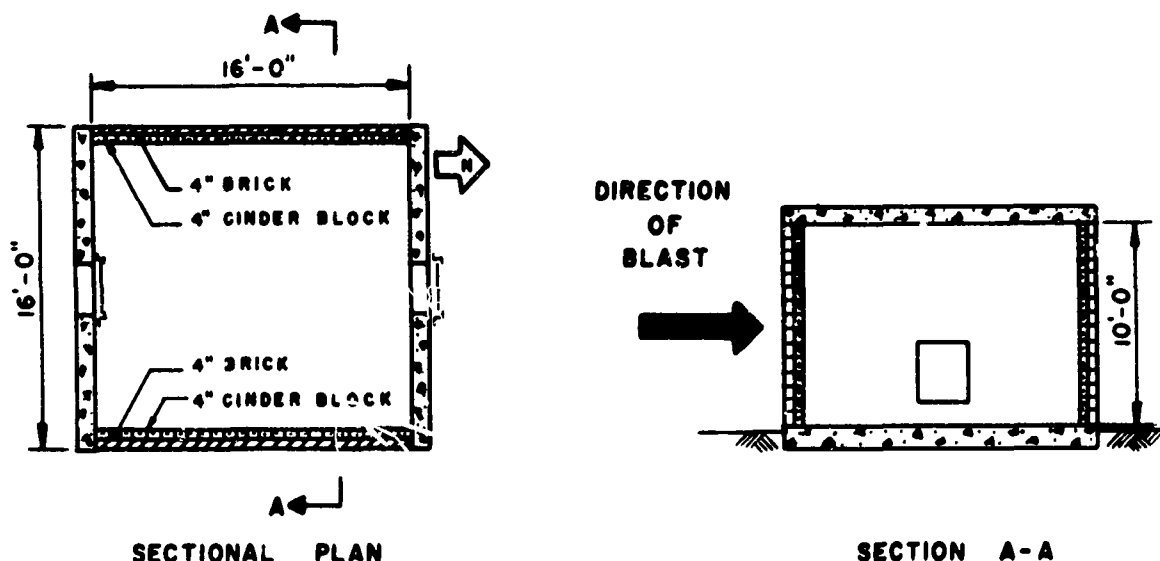


Fig. 2.133 Motion Picture Sequence - Front Wall - Cell No. 10c



Fig. 2.134 Post Shot - Front Wall Detail - Cell No. 10c

# CELL NO. 11c 10'x16' OPENING



## DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing with 4 in. cinder block backing. Standard brick ties were placed every 6th course and at 4 ft on centers with mortar joints at the top and bottom and dovetail anchors and mortar joints at the side edges.

## CONSTRUCTION ERRORS AND OMISSIONS:

None

## FIELD DAMAGE NOTES:

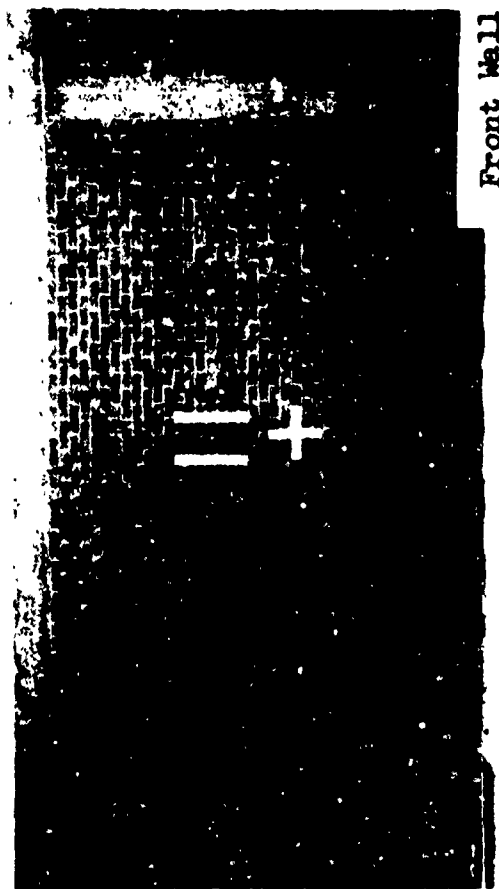
The front wall was blown into and thru the cell except for 1 course at the floor and the bottom fillets.

The rear wall was 85 percent blown out.

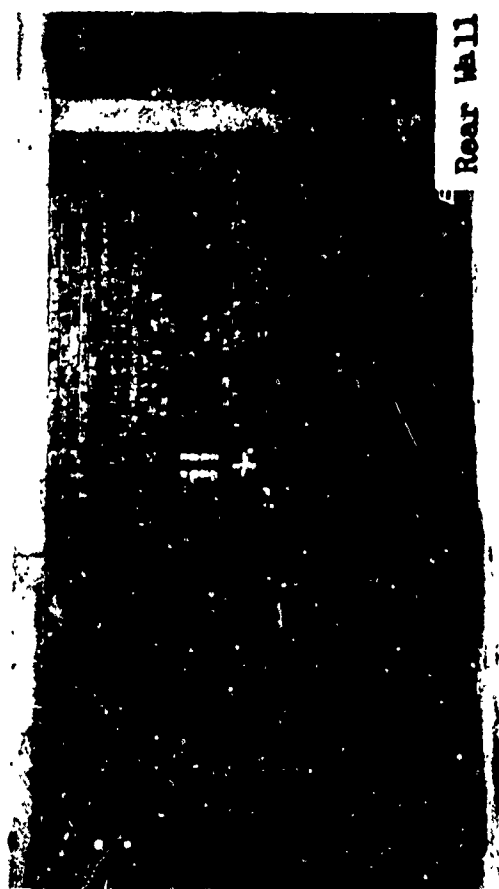
The measured, pre shot, natural frequencies of the front and rear walls were 22.6 cps and 25.7 cps, respectively.



Fig. 2.137 Motion Picture Sequence - Front Wall - Cell No. 11c



Front Wall



Rear Wall

Fig. 2.135 Pre Shot Photography - Cell No. 11c



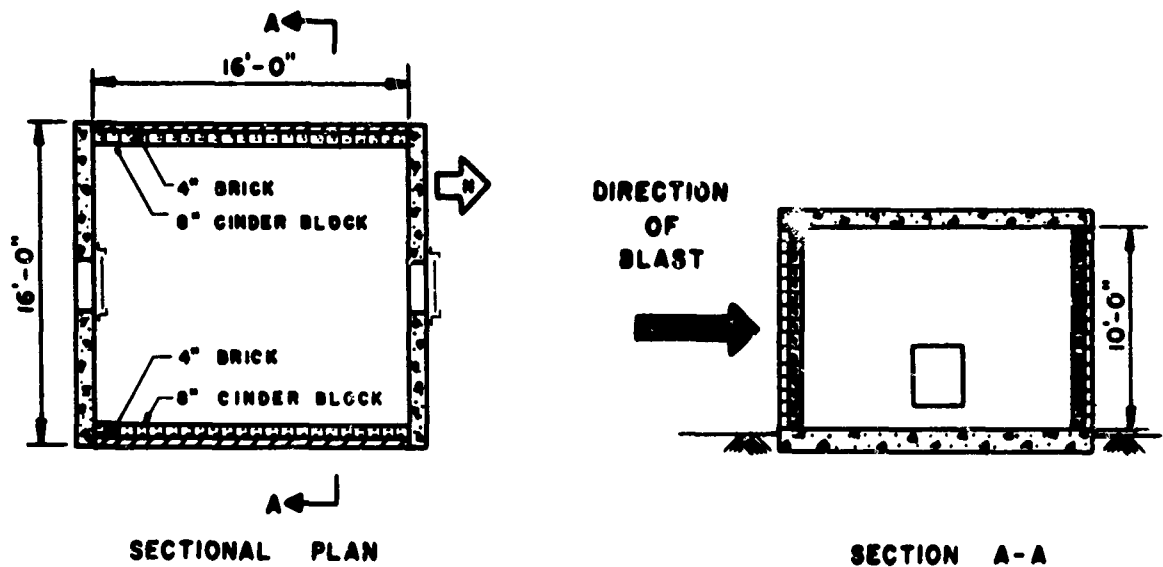
Front Wall



Rear Wall

Fig. 2.136 Post Shot Photography - Cell No. 11c

# CELL NO. 12 c 10' x 16' OPENING



## DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing with 8 in. cinder block backing. Standard brick ties were placed every 6th course and at 4 ft on centers. The bottom had a mortar joint and an angle for bearing on the inside. The top had a 3/4 in. open joint and an angle for bearing on the inside. The side edges had dovetail anchors and mortar joints.

## CONSTRUCTION ERRORS AND OMISSIONS:

None

## FIELD DAMAGE NOTES:

The front wall was 85 percent blown into the back of the cell with approximately a 1 ft border remaining at the side edges and the bottom. A cinder block "beam" remained across the top.

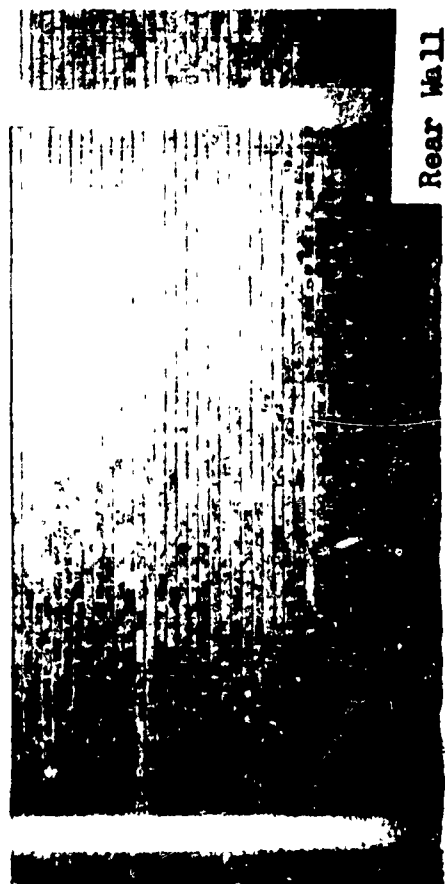
The rear wall had a crack on both faces extending vertically from the top down 5 courses at the center. Several holes were punched into the block cells but no openings thru to the back.

The measured, pre shot, natural frequency of the front wall was 14.2 cps. For the rear wall, the measured, pre shot and post shot, natural frequencies were 25.3 cps and 10.5 cps, respectively.

Fig. 2.140 Motion Picture Sequence - Front Wall - Cell No. 12c

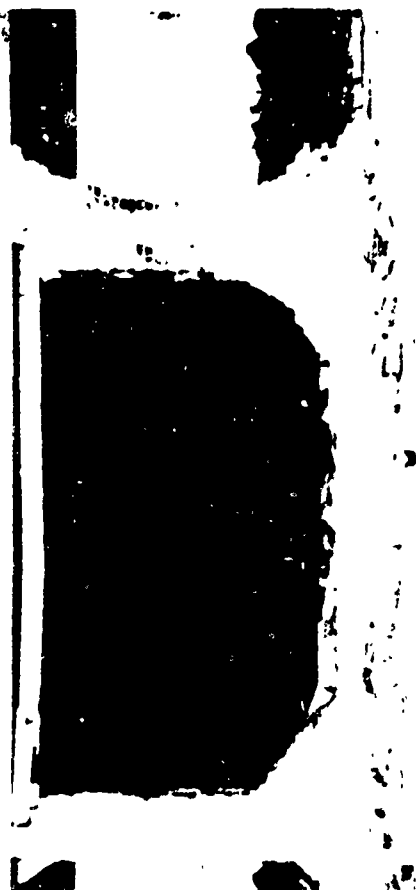


Front Wall

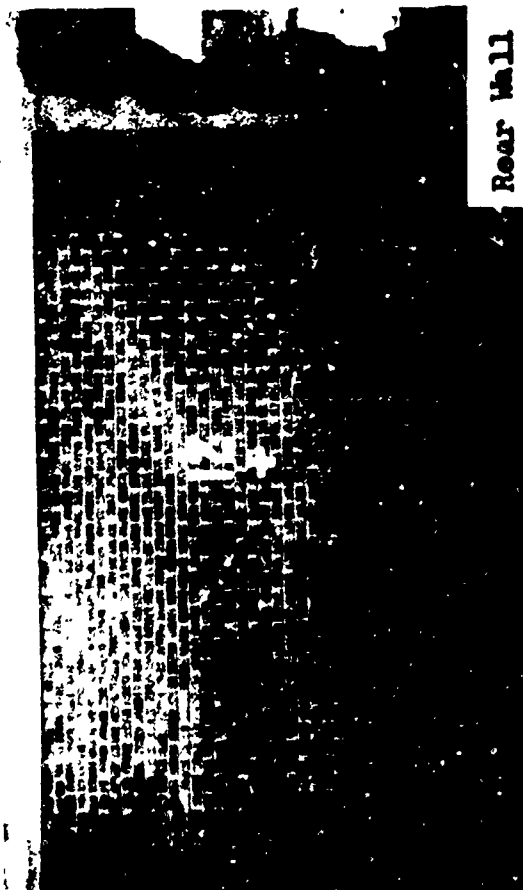


Rear Wall

Fig. 2.138 Pre Shot Photography - Cell No. 12c



Front Wall



Rear Wall

Fig. 2.139 Post Shot Photography - Cell No. 12c

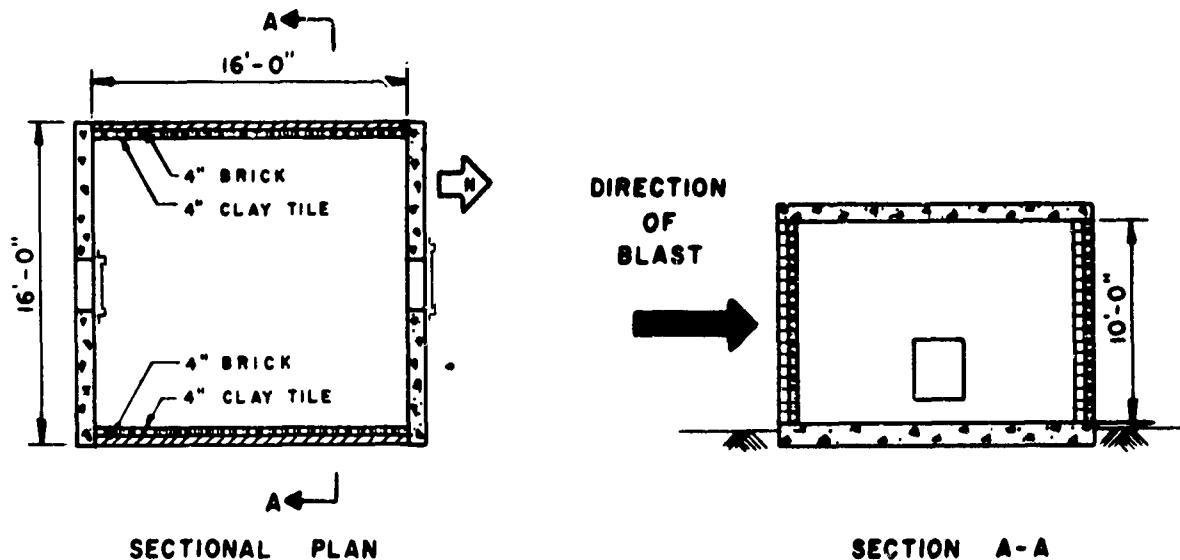


Fig 2.142 Post Shot - Front Wall Detail  
Cell No. 12c



Fig 2.141 Post Shot - Front Wall Detail  
Cell No. 12c

# CELL NO. 13c 10'x16' OPENING



## DESCRIPTION.

The front and rear walls consisted of 4 in. brick facing with 4 in. clay tile backing. Standard brick ties were placed at all tile joints except at the top and bottom. There were mortar joints at the top and bottom and dovetail anchors and mortar joints at the side edges.

## CONSTRUCTION ERRORS AND OMISSIONS:

None

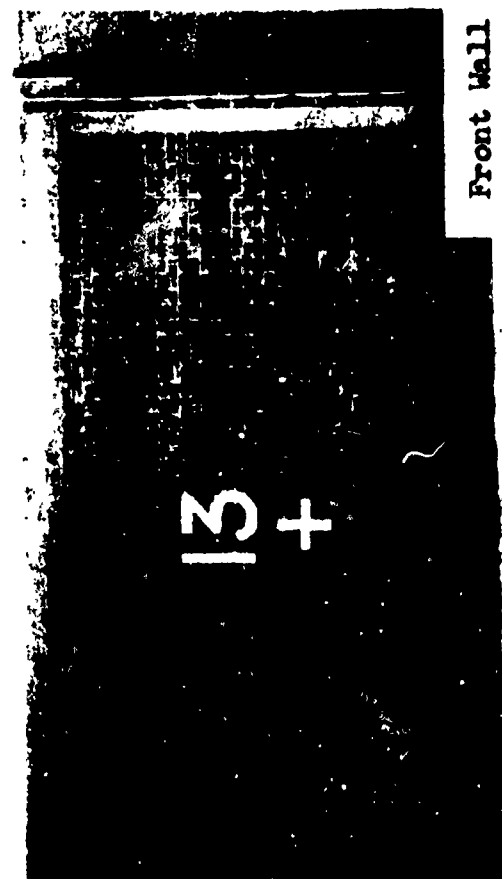
## FIELD DAMAGE NOTES:

The front wall was 95 percent blown into and thru the cell.

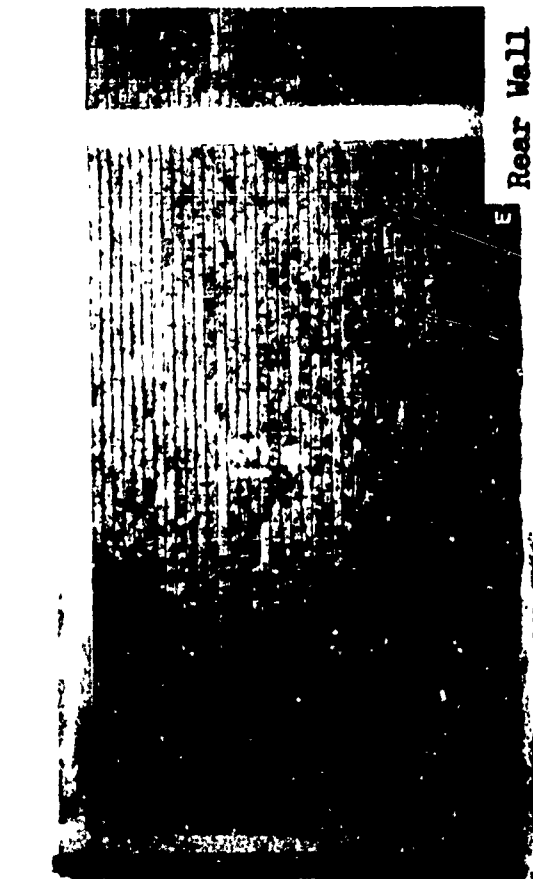
The rear wall was 65 percent blown out.

The measured, pre shot, natural frequency of the rear wall was 34.5 cps.





Front Wall

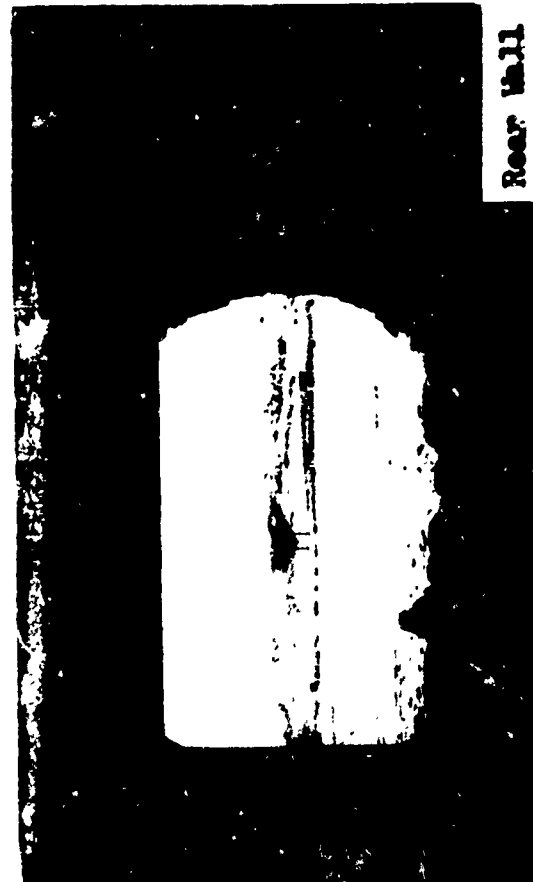


Rear Wall

Fig. 2.143 Pre Shot Photography - Cell No. 13c



Front Wall



Rear Wall

Fig. 2.144 Post Shot Photography - Cell No. 13c

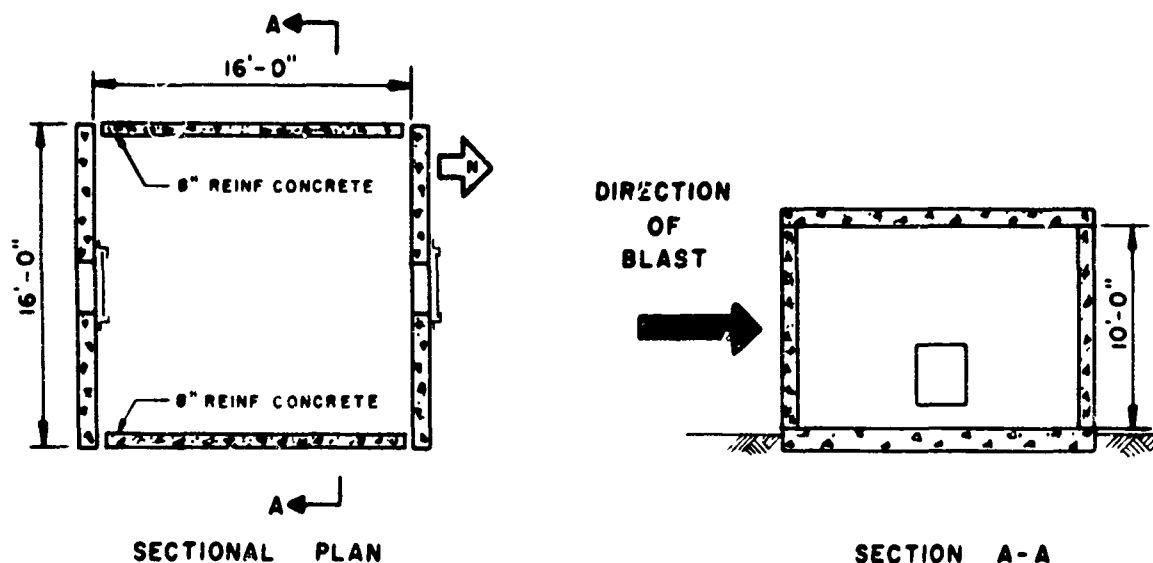


Fig. 2.145 Post Shot - Interior -  
Cell No. 13c



Fig. 2.146 Post Shot - Rear Wall Detail -  
Cell No. 13c

### CELL NO. 14c 10'x16' OPENING



#### DESCRIPTION.

The front and rear walls consisted of 8 in. reinforced concrete with keyed joints at the top and bottom. Each of the side edges had an angle extending from the top of the roof slab to the bottom of the floor slab for a fibre glass cloth blast closure of the joints.

#### CONSTRUCTION ERRORS AND OMISSIONS:

The angles, holding the fibre glass cloth, should not have extended above the bottom of the roof slab or below the top of the floor slab.

#### FIELD DAMAGE NOTES:

The front wall had a 1 ft horizontal crack on the outside face near the south edge at the ground and a hair line opening of the construction joint.

The maximum recorded displacements of the front and rear walls were 0.62 in. and 0.20 in., respectively.

The measured, pre shot, natural frequency of the front wall was 75.0 cps. For the rear wall, the measured, pre shot and post shot, natural frequencies were 68.8 cps and 60.8 cps, respectively.

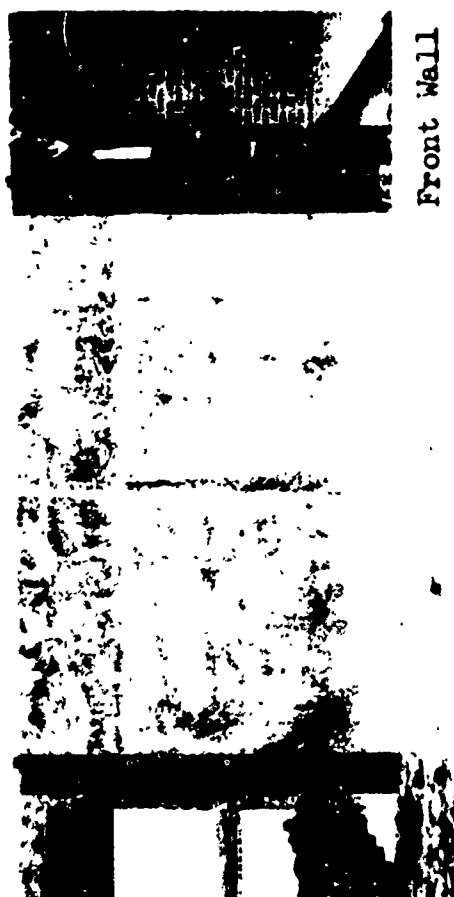


Front Wall

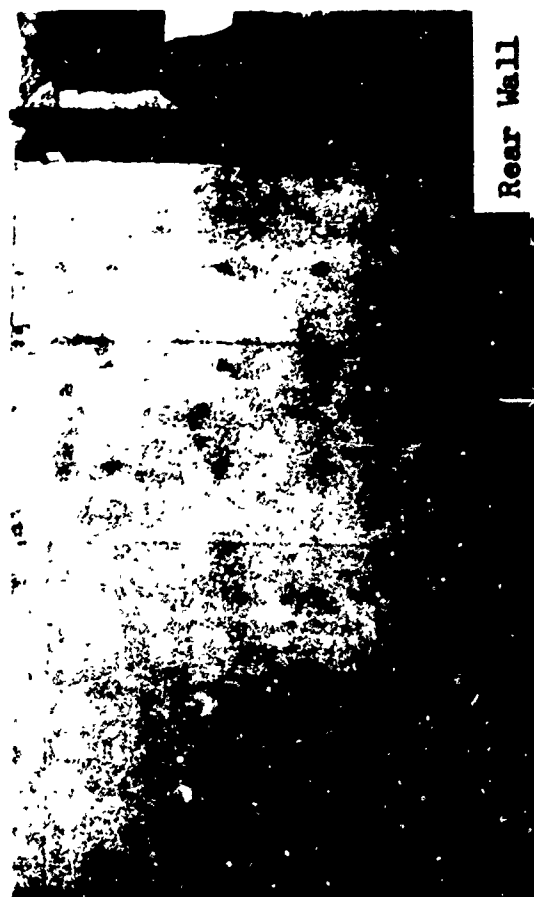


Rear Wall

Fig. 2.147 Pre Shot Photography - Cell No. 14c



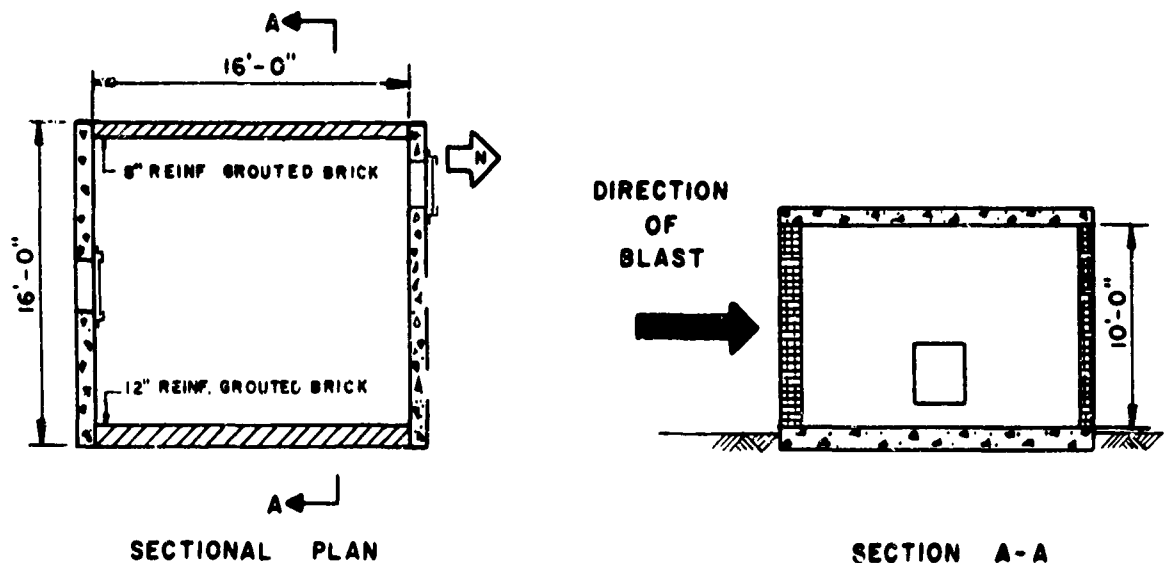
Front Wall



Rear Wall

Fig. 2.148 Post Shot Photography - Cell No. 14c

## CELL NO. 15c 10'x16' OPENING



### DESCRIPTION

The front and rear walls consisted of 12 in. and 8 in. reinforced grouted brick respectively. Continuous bars were placed from the walls into the floor slab. Each of the side edges had an angle extending from the top of the roof slab to the bottom of the floor slab for a fibre glass cloth blast closure of the joints.

### CONSTRUCTION ERRORS AND OMISSIONS:

A 4-1/4 in. recess for horizontal bearing of the front and rear walls should have been provided in the floor and roof slabs. Continuous bars from the walls into the roof slab were omitted. The angles, holding the fibre glass cloth, should not have extended above the bottom of the roof slab or below the top of the floor slab.

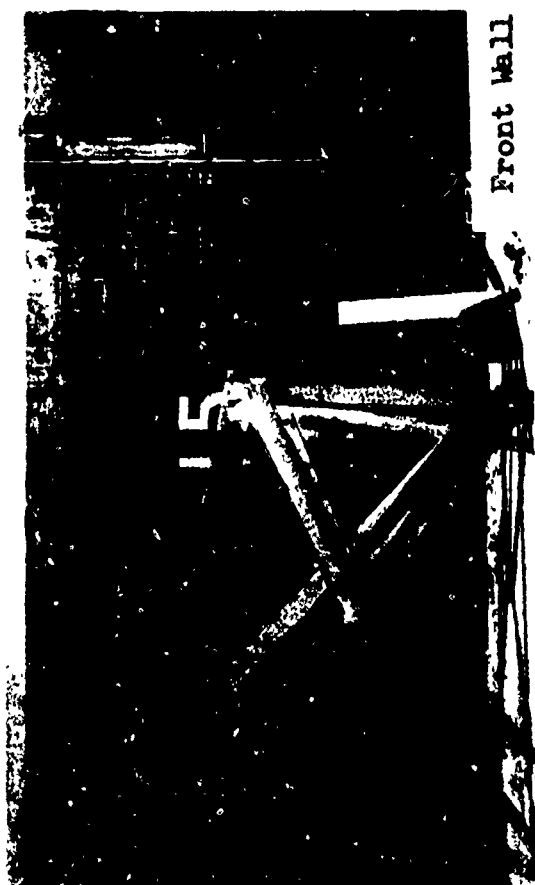
### FIELD DAMAGE NOTES:

The front wall had minor cracking, but was bowed in 1 ft at the top. The wall was restrained by the side angles which were bent. Two 4 ft cracks from the top down to the center of the outside face were found.

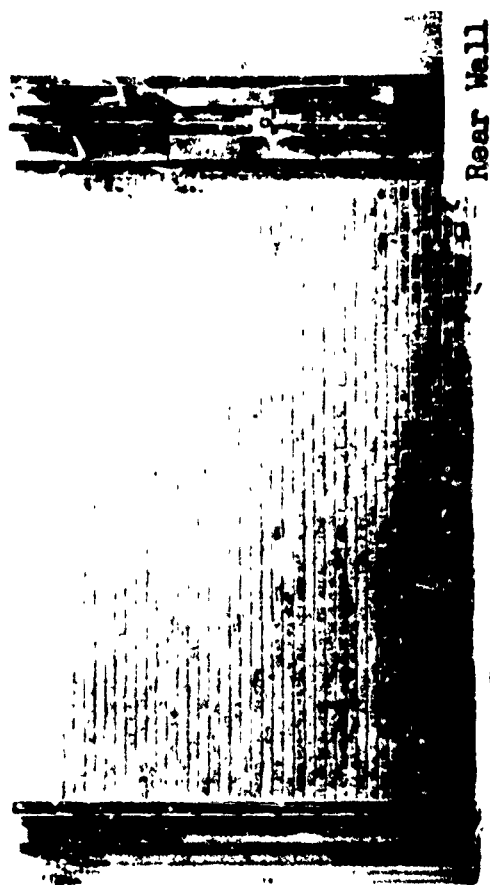
The rear wall was spalled, at the top, on the outside face. On the inside face there was a 3 ft crack from the top down near the center.

The maximum recorded displacements of the front and rear walls were 0.89 in. and 4.47 in., respectively. (The displacement of 4.47 in. appears to be inconsistent with observed field damage.)

The measured, pre shot and post shot, natural frequencies of the front wall were 32.9 cps and 65.5 cps, respectively. For the rear wall, the pre shot and post shot, natural frequencies were 26.6 cps and 22.7 cps, respectively.



Front Wall



Rear Wall

Fig. 2.149 Pre Shot Photography - Cell No. 15c



Front Wall



Rear Wall

Fig. 2.150 Post Shot Photography - Cell No. 15c



Fig. 2.151 Motion Picture Sequence - Front Wall - Cell No. 15c



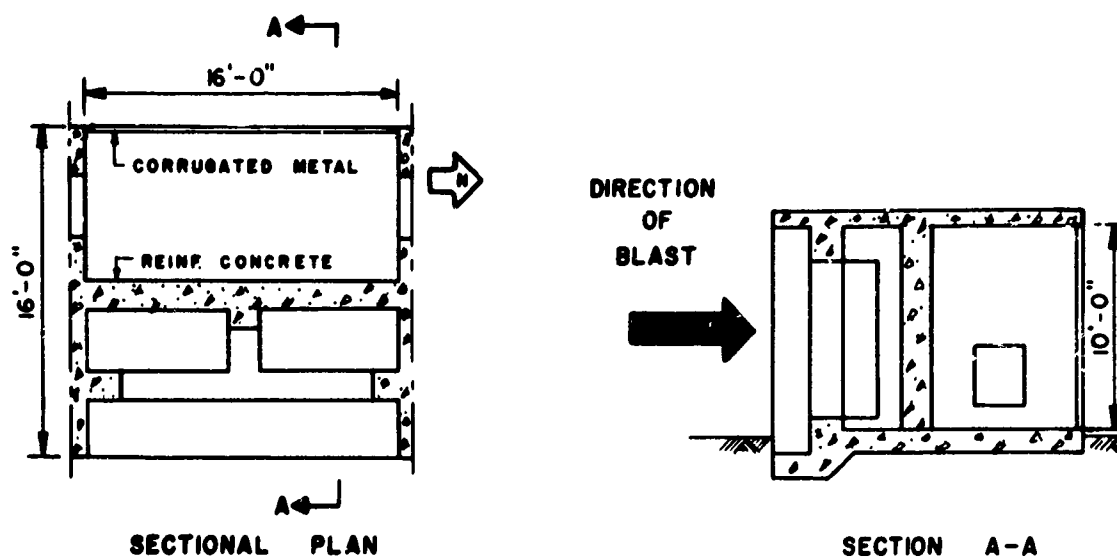
Fig 2.153 Post Shot - Front Wall Detail  
Cell No. 15c



Fig 2.152 Post Shot - Front Wall Detail  
Cell No. 15c



# CELL NO.16c 10'x 16' OPENING



## DESCRIPTION:

The rear wall consisted of 22 gage corrugated metal on structural steel girts spanning horizontally at the roof level and mid-height and a structural steel angle spanning horizontally at the floor level. A 1-1/2 in. opening between the metal and the bottom of the roof slab was covered with fibre glass cloth for blast closure.

## CONSTRUCTION ERRORS AND OMISSIONS:

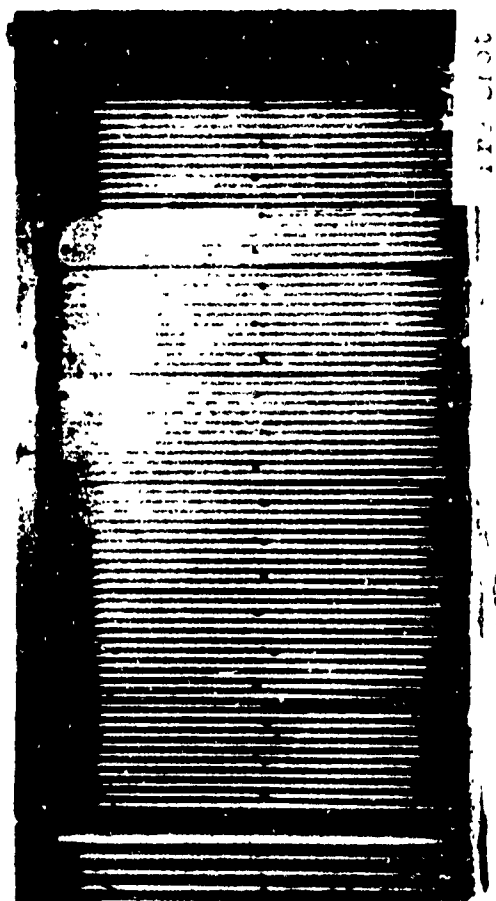
None

## FIELD DAMAGE NOTES:

The middle girt and the bottom angle were torn loose and blown into the cell. The top girt was twisted and bowed in. Three sheets were hanging by the top bolts though torn loose at the bottom. Four other sheets were loose on the ground.



Post Shot



Post Shot

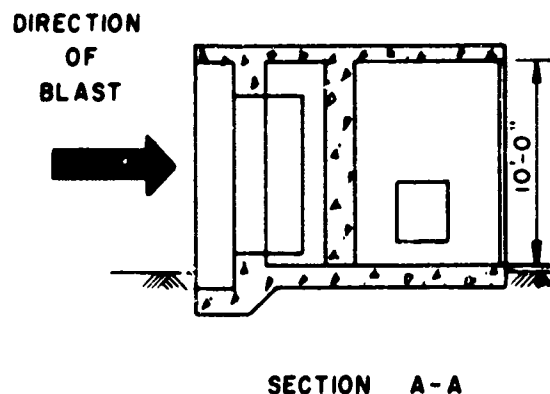
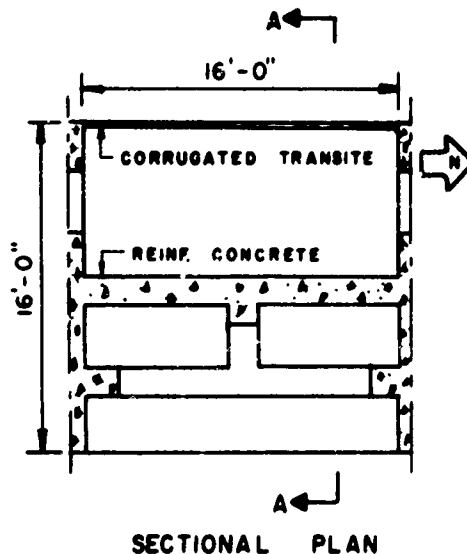
Fig. 2.154 Rear Wall - Cell No. 16c

Front Wall Not Tested



Fig. 2.155 Post Shot - Interior - Cell No. 16c

# CELL NO 17c 10'x16' OPENING



## DESCRIPTION.

The rear wall consisted of corrugated cement asbestos on structural steel girts spanning horizontally at the roof level and mid-height and a structural steel angle spanning horizontally at the floor level. A 1-1/2 in. opening between the corrugated siding and the bottom of the roof slab was covered with fibre glass cloth for blast closure.

## CONSTRUCTION ERRORS AND OMISSIONS:

None

## FIELD DAMAGE NOTES:

All the cement asbestos was broken up and blown into the cell. The middle girt was bowed in about 3 in. at the center.



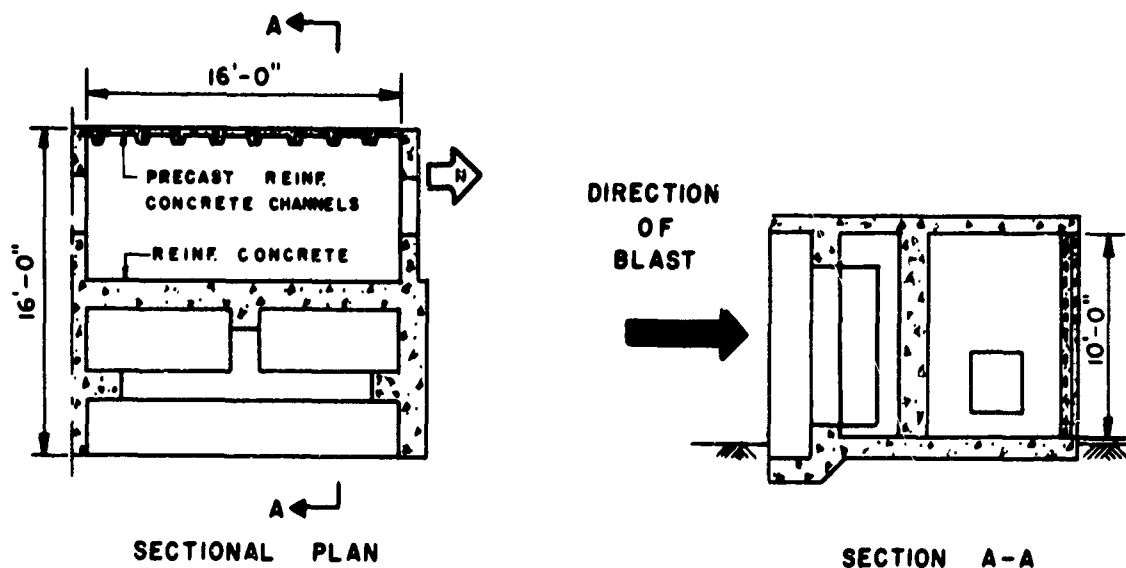
Fig. 2.156 Rear Wall - Cell No. 17c

Front Wall Not Tested



Fig 2.157 Post Shot - Rear Wall Detail  
Cell No. 17c

# CELL NO.18c 10'x16' OPENING



## DESCRIPTION.

The rear wall consisted of precast concrete channel slabs with the top and bottom bearing against and bolted to angles. There was a 1 in. gap between the top of the wall and the bottom of the roof slab. Each of the side edges had an angle extending from the top of the roof slab to the bottom of the floor slab for a fibre glass cloth blast closure of the joints.

## CONSTRUCTION ERRORS AND OMISSIONS:

The angles, holding the fibre glass cloth, should not have extended above the bottom of the roof slab or below the top of the floor slab.

## FIELD DAMAGE NOTES:

All panels failed, except the end panels which had partial failure. The large flange bars broke out of the panels. Failure was proportional to distance from corner of the building.



Pre Shot



Post Shot

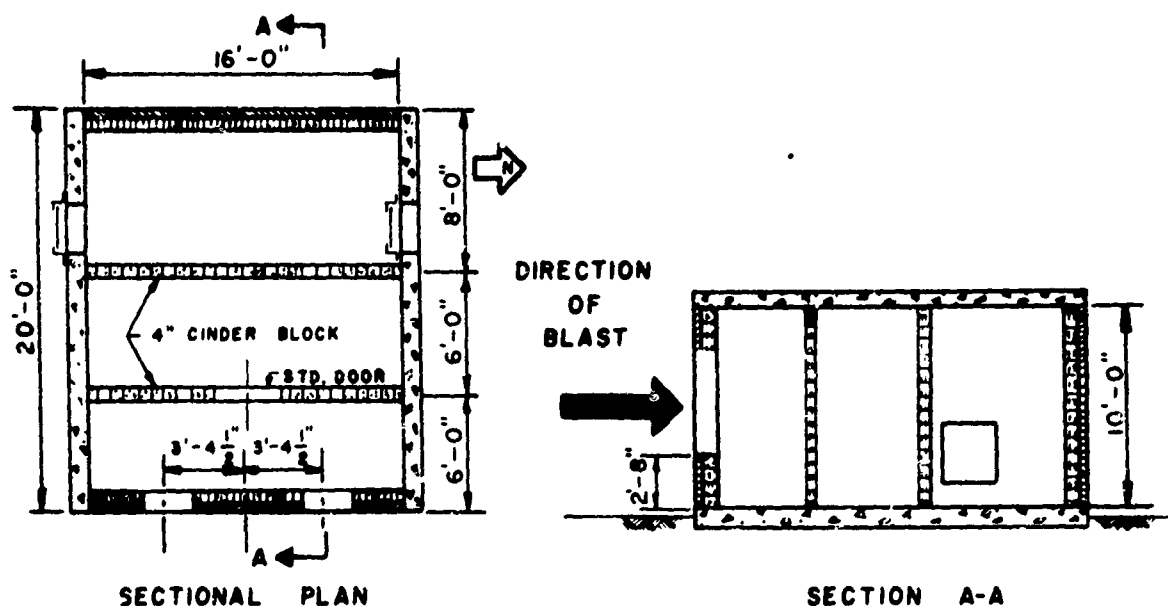
Fig. 2.158 Rear Wall - Cell No. 18c

Front Wall Not Tested



Fig 2.159 Post Shot - Interior -  
Rear Wall - Cell No. 18c

# CELL NO. 1d 10'x16' OPENING



## DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing and 8 in. cinder block backing. There were two windows in the front wall, 3 ft 3 in. by 5 ft 5 in. The partitions were 4 in. cinder block with 3/4 in. plaster on each face. The partitions had mortar joints at the top and bottom, and dovetail anchors and mortar joints at the side edges. The front partition had a standard, 3 ft by 6 ft 8 in., door in the center.

## CONSTRUCTION ERRORS AND OMISSIONS:

None

## FIELD DAMAGE NOTES:

The partitions were destroyed and the debris blown to the rear of the cell and piled against the rear wall.

The front wall was bowed in 1/4 in., between the windows, at the top of the 6th cinder block course. The outside face was spalled at the top and the top of the window frames bowed in. The inside lintel was half out of the wall.

The rear wall was bowed out 1 in. on the outside face, at the top, right of center, with a vertical crack running from the top to the bottom. The south edge of wall was pushed out 1/2 in at the center. The inside face of the rear wall was punctured by missiles.

The measured, pre shot and post shot, natural frequencies of the front wall were 37.0 cps and 23.1 cps, respectively. For the rear wall, the measured, pre shot and post shot, natural frequencies were 38.2 cps and 14.5 cps, respectively.

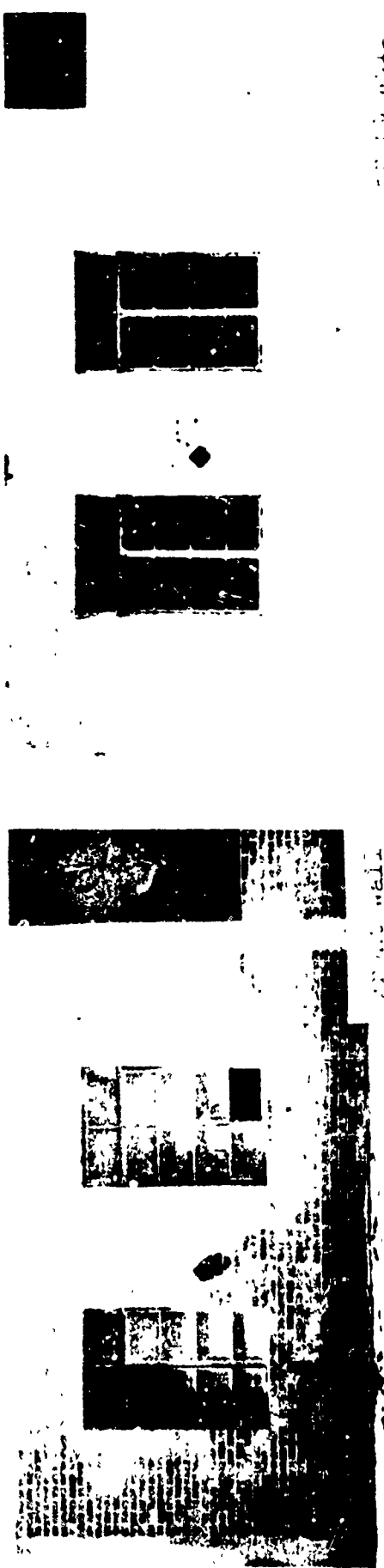


Fig. 2.160



Fig. 2.161

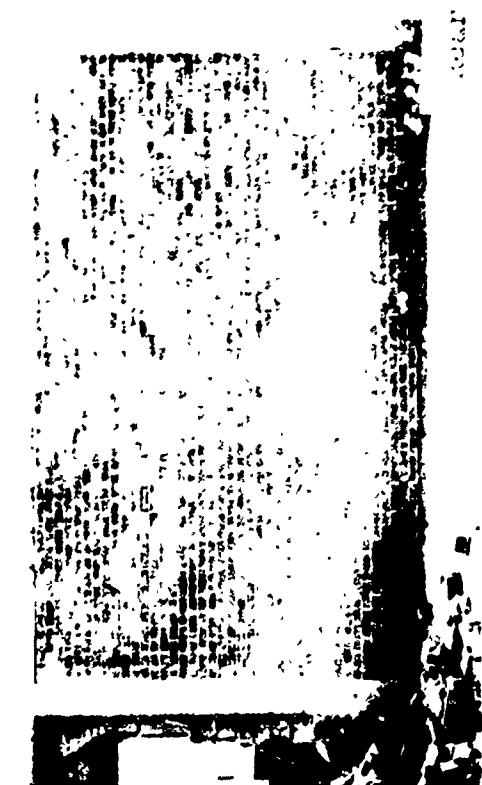


Fig. 2.162

Fig. 2.160 Pre Shot Photography - Cell No. 1d

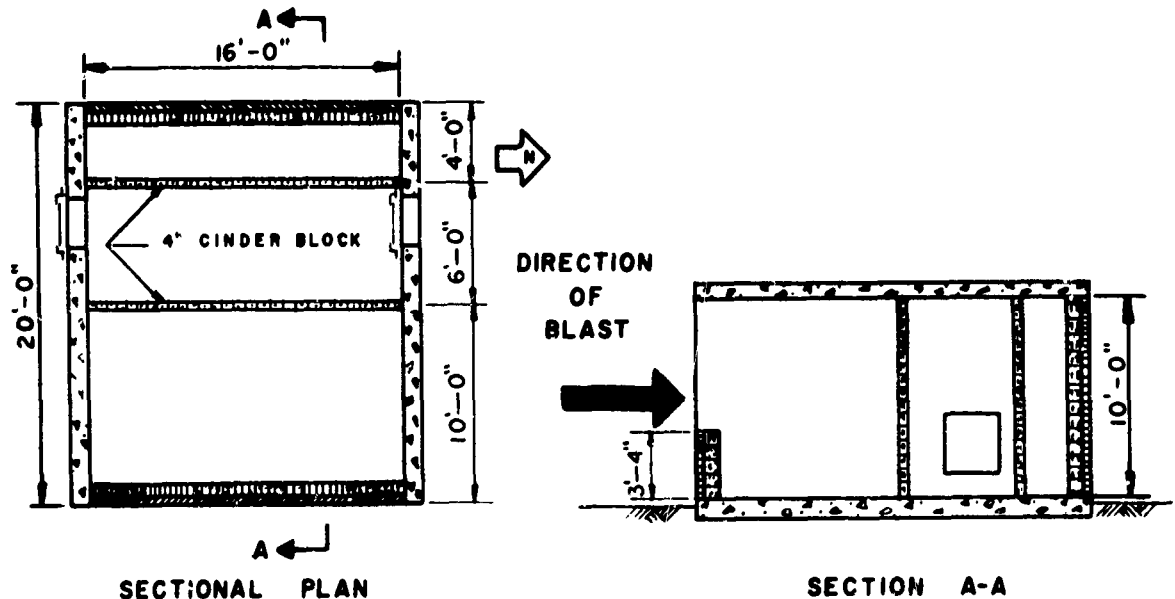
Fig. 2.161 Post Shot Photography - Cell No. 1d





Fig. 2.162 Post Shot - Interior - Cell No. 1d

# CELL NO.2d 10'x16' OPENING



## DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing and 8 in. cinder block backing. The front wall was 3 ft 4 in. high. The partitions were 4 in. cinder block with 3/4 in. plaster on each face. The partitions had mortar joints at the top and bottom, and dovetail anchors and mortar joints at the side edges.

## CONSTRUCTION ERRORS AND OMISSIONS:

None

## FIELD DAMAGE NOTES:

The partitions were destroyed except for fillets.

The front wall was cracked vertically across its entire length.

The rear wall was destroyed except for 1 ft at each edge. All debris was either outside of the cell or beyond the rear partition.

The measured, pre shot, natural frequency of the rear wall was 53.2 cps.

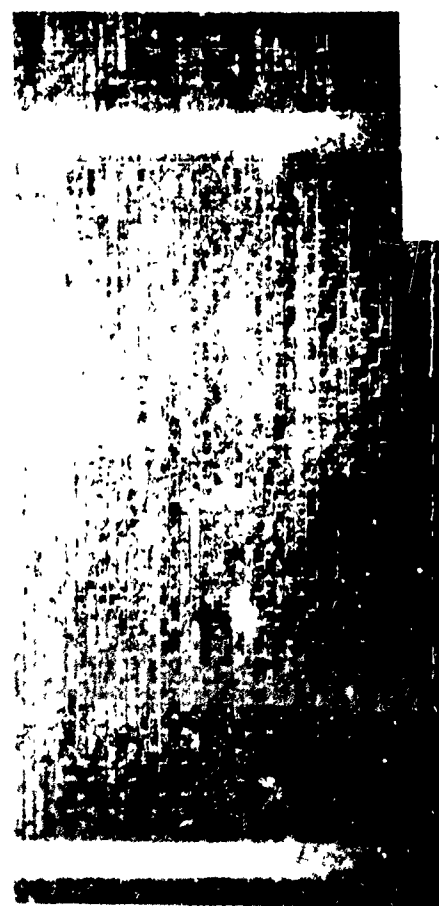
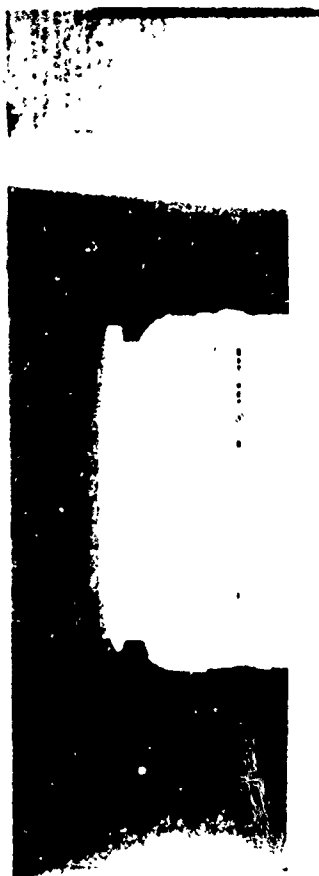


Fig. 2.163 Pre Shot Photography - Cell No. 2d



front wall



Fig. 2.164 Post Shot Photography - Cell No. 2d

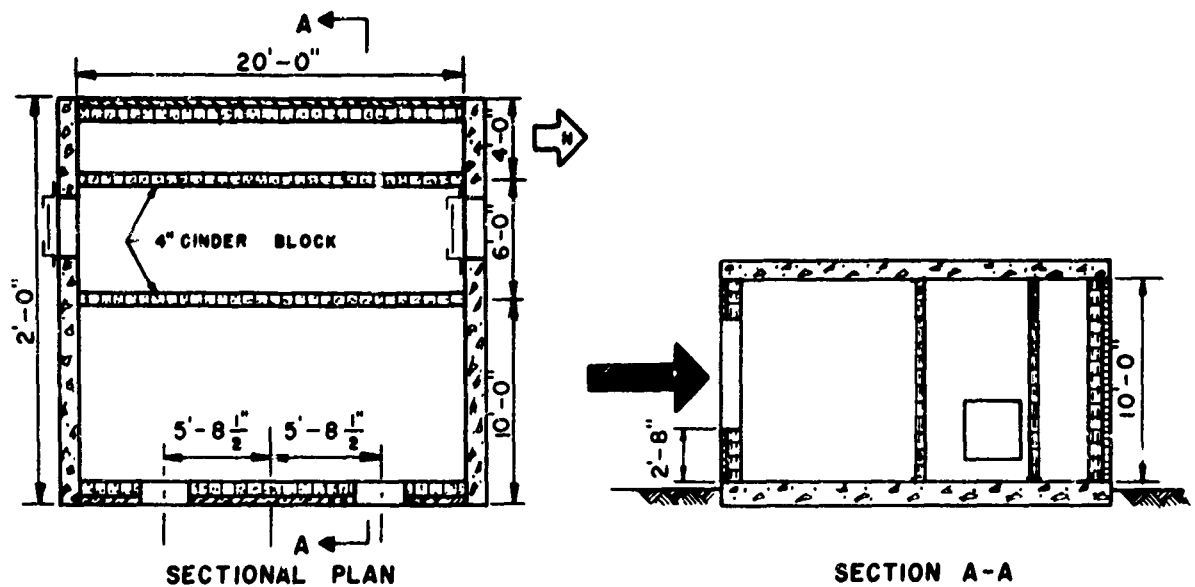


Fig. 2.165 Post Shot - Interior - Cell No. 2d



Fig. 2.166 Post Shot - Interior - Cell No. 2d

# CELL NO. 3d 10'x20' OPENING



## DESCRIPTION:

The front and rear walls consisted of 1/4 in. brick facing and 8 in. cinder block backing. There were two windows in the front wall, 3 ft 3 in. by 5 ft 5 in. The partitions were 1/4 in. cinder block with 3/4 in. plaster on each face. The partitions had mortar joints at the top and bottom, and dovetail anchors and mortar joints at the side edges.

## CONSTRUCTION ERRORS AND OMISSIONS:

None

## FIELD DAMAGE NOTES:

The partitions were destroyed except for fillets with debris piled against the rear wall.

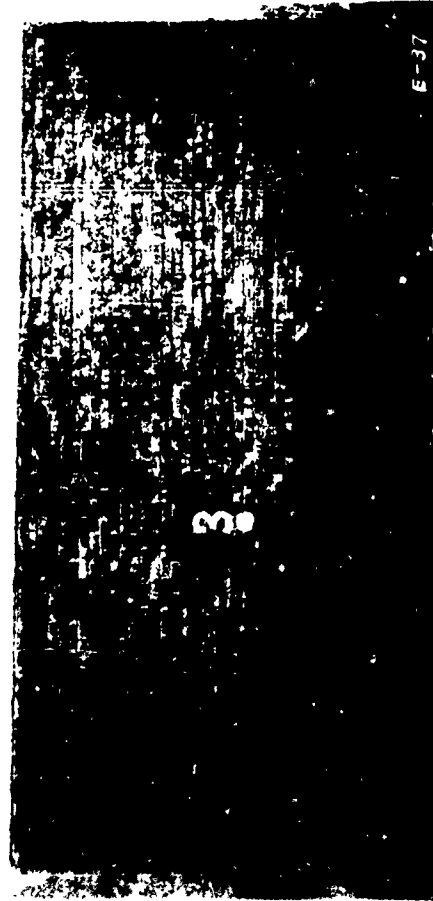
The front wall, center section, was bowed in 1/2 in. at sill height. The top of the front wall was bowed in 1/4 in. at the center. The window frames were bowed in at the top of the swinging sash with the vertical muntins broken out. The front wall appeared on the verge of failure with vertical cracks at the jambs, above the windows, and horizontal cracks below the sills.

The rear wall was badly bowed out at the center.

The measured, pre shot and post shot, natural frequencies of the front wall were 33.3 cps and 16.8 cps, respectively. For the rear wall, the measured, pre shot, natural frequency was 50.0 cps.

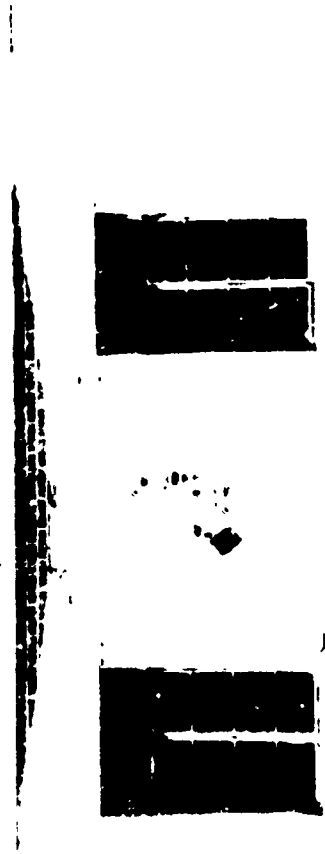


FRONT WALL



REAR WALL

Fig. 2.167 Pre Shot Photography - Cell No. 3d



FRONT WALL



REAR WALL

Fig. 2.168 Post Shot Photography - Cell No. 3d



Fig. 2.169 Post Shot - Interior - Cell No. 3d

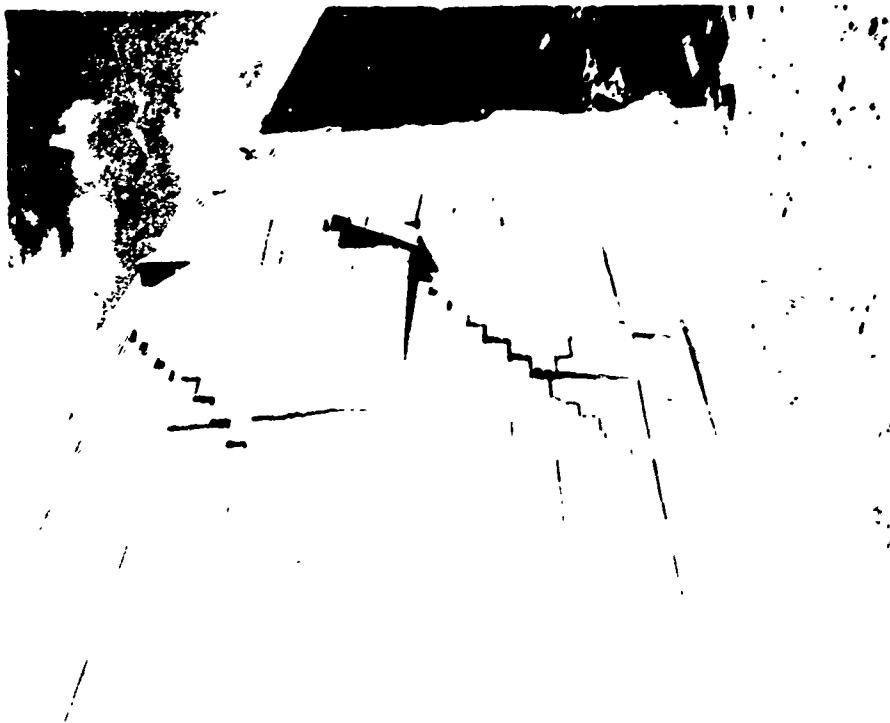


Fig. 2.170 Post Shot - Rear Wall Detail  
Cell No. 3d



Fig. 2.171 Post Shot - Front Wall Detail  
Cell No. 3d

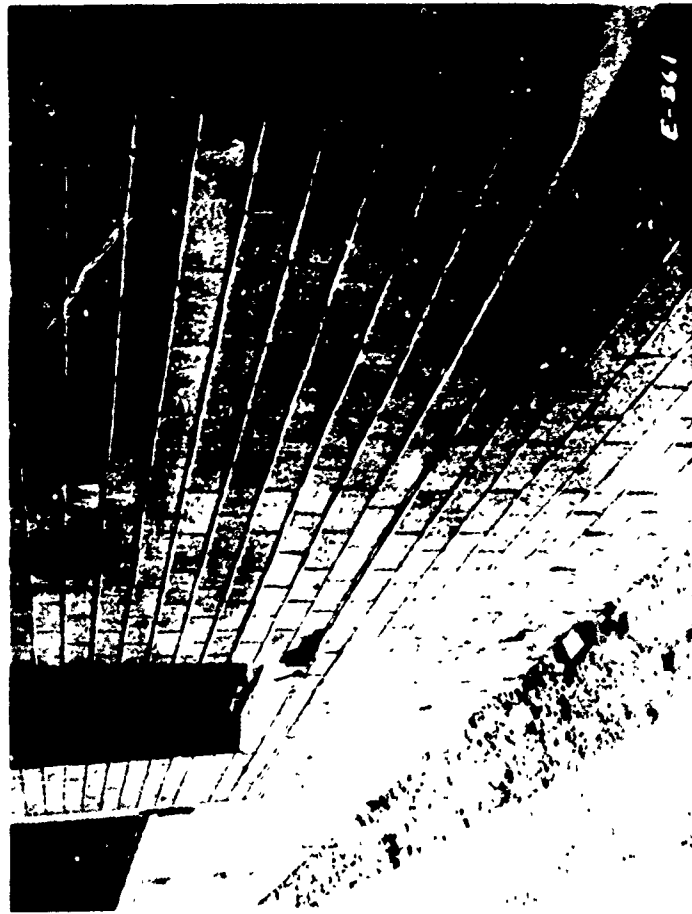
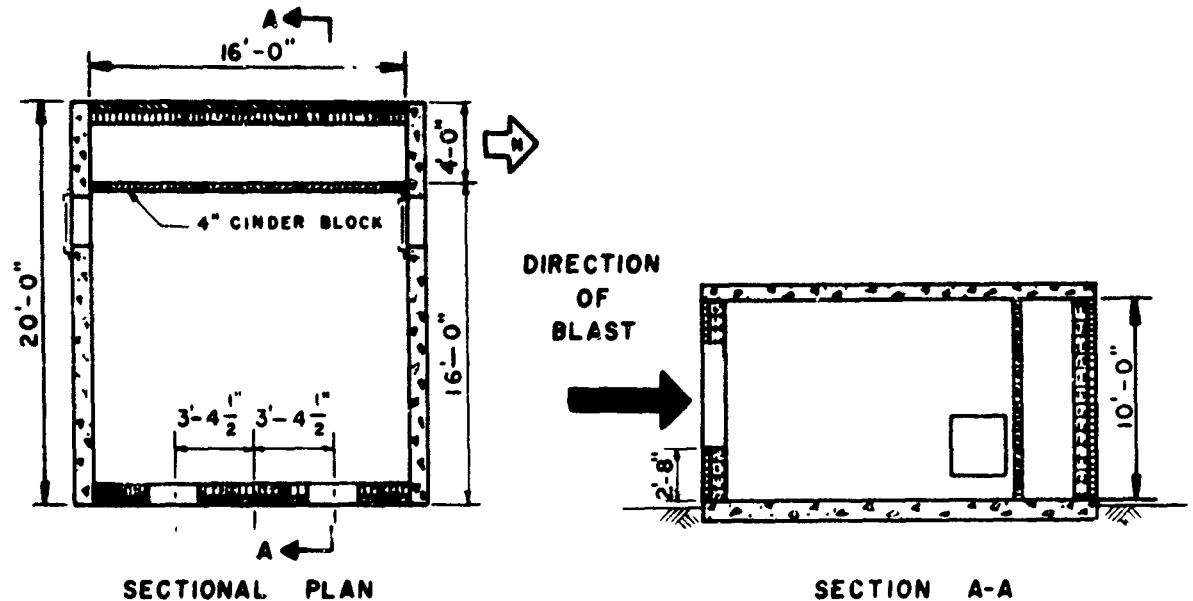


Fig. 2.172 Post Shot - Front Wall Detail  
Cell No. 3d



# CELL NO. 4d 10'x16' OPENING



## DESCRIPTION.

The front and rear walls consisted of 4 in. brick facing and 8 in. cinder block backing. There were two windows in the front wall, 3 ft 3 in. by 5 ft 5 in. The partition was 4 in. cinder block with 3/4 in. plaster on each face. The partition had mortar joints at the top, bottom, and side edges.

## CONSTRUCTION ERRORS AND OMISSIONS:

Dovetail anchors were omitted at the side edges of the partition. Mortar was missing between the top row of cinder blocks in the rear wall and the roof slab.

## FIELD DAMAGE NOTES:

The partition was destroyed and debris was piled against the rear wall. There were side wall markings indicating that the partition failed horizontally at mid-height.

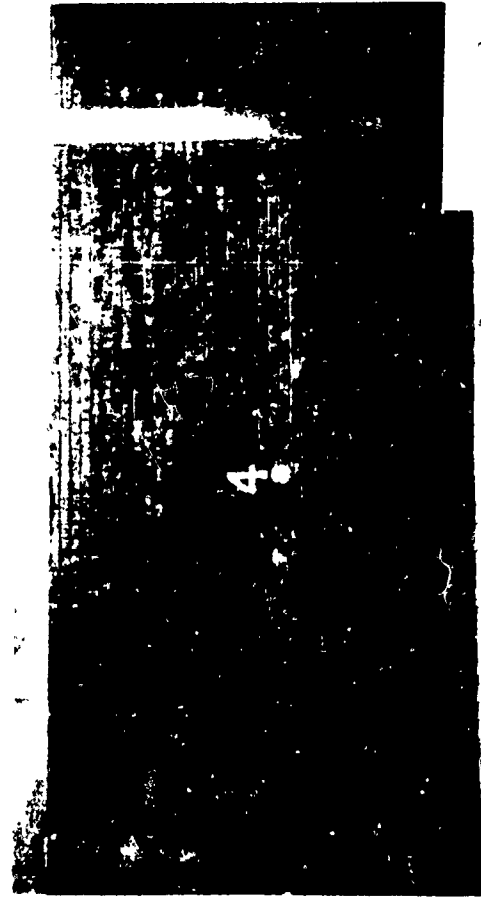
The front wall was bowed in 1/2 in. at the center section at the sill line. The top of the front wall was bowed in 1/2 in. at the center. The window frames were bowed in.

The rear wall was bowed out 1/2 in. at the top.

The measured, pre shot and post shot, natural frequencies of the front wall were 34.7 cps and 9.7 cps, respectively. For the rear wall, the measured, pre shot and post shot, natural frequencies were 52.2 cps and 15.8 cps, respectively.

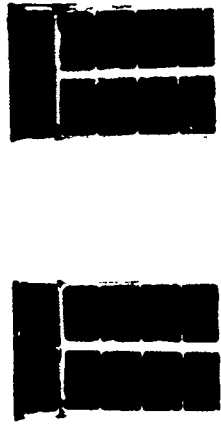


Front wall



Near wall

Fig. 2.173 Pre Shot Photography  
Cell No. 4d



Front wall



Near wall

Fig. 2.174 Post Shot - Photography  
Cell No. 4d

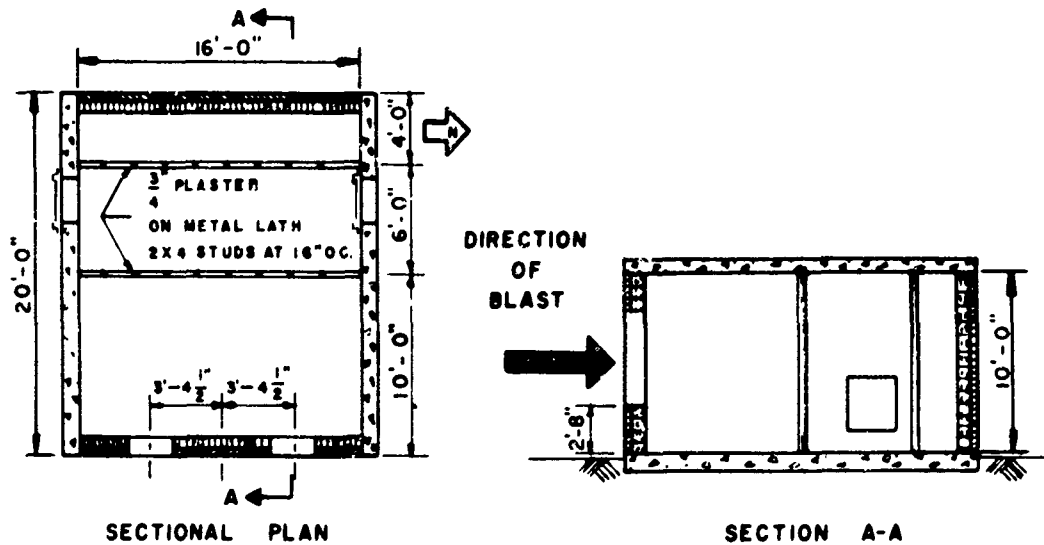


Fig. 2.175 Post Shot - Interior  
Cell No. 4d



Fig. 2.176 Post Shot - Front Wall Detail  
Cell No. 4d

# CELL NO. 5d 10'x16' OPENING



## DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing and 8 in. cinder block backing. There were two windows in the front wall 3 ft 3 in. by 5 ft 5 in. The partitions consisted of 2 in. by 4 in. wood studs, at 16 in. on centers, with 3/4 in. plaster or metal lath on each face. The partitions had 2 in. by 4 in. plates at the top and bottom.

## CONSTRUCTION ERRORS AND OMISSIONS:

Dovetail anchors at the side edges were omitted. Anchorage of the plates to the roof and floor slabs with cut nails was omitted. The only support was due to the bond of the plaster to the respective surfaces.

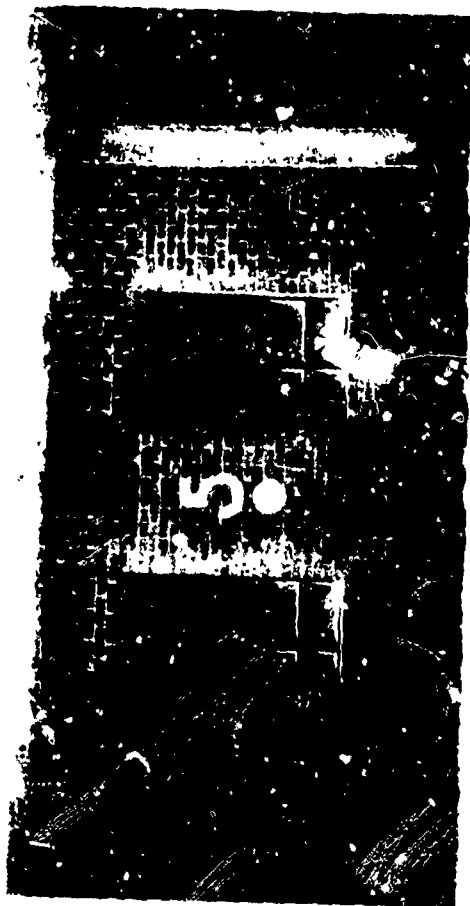
## FIELD DAMAGE NOTES:

The partitions were blown over and carried out thru the rear of the cell. The front partition floor plate was displaced 2 ft to the rear.

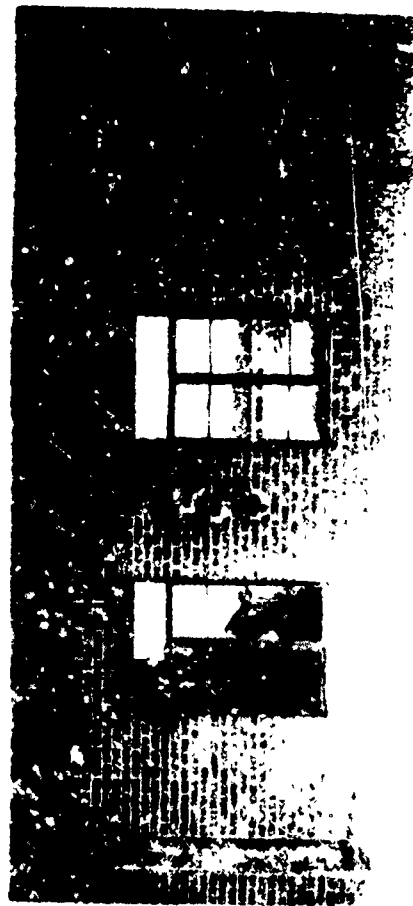
The front wall was cracked at the sill line on the outside face. The window frames were bowed in with the upper muntins blown out. The inside face was cracked horizontally 2 block courses high.

The rear wall was blown out except for 1 ft at the side edges.

The measured, pre shot and post shot, natural frequencies of the front wall were 36.6 cps and 19.5 cps, respectively. For the rear wall, the measured pre shot, natural frequency was 50.0 cps.



Front Wall



Front Wall



Front Wall



Front Wall

Fig. 2.177 Pre Shot Photography - Cell No. 5d

Fig. 2.178 Post Shot Photography - Cell No. 5d

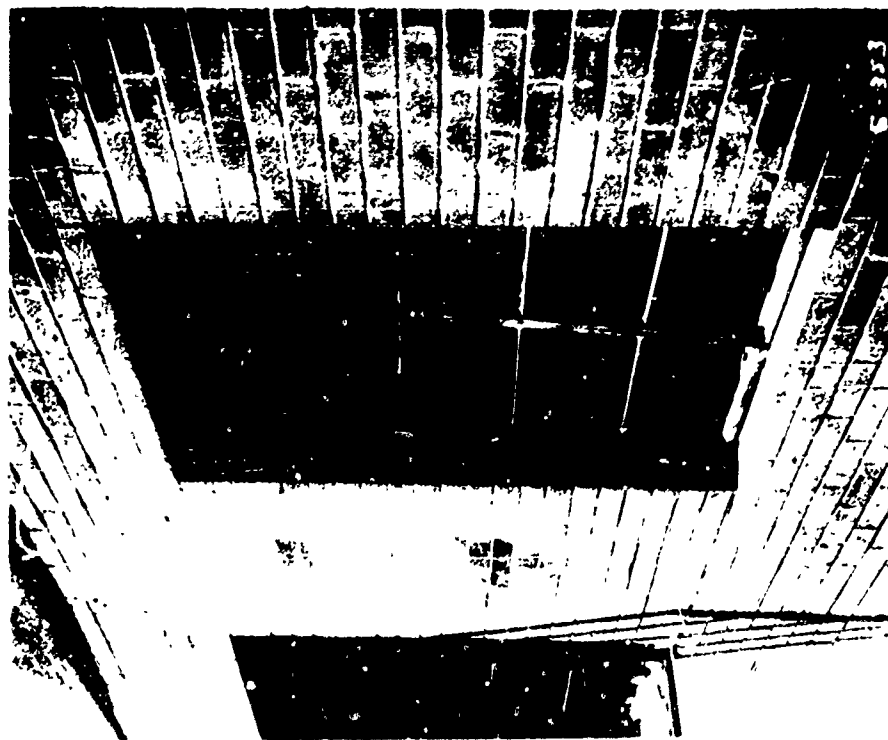
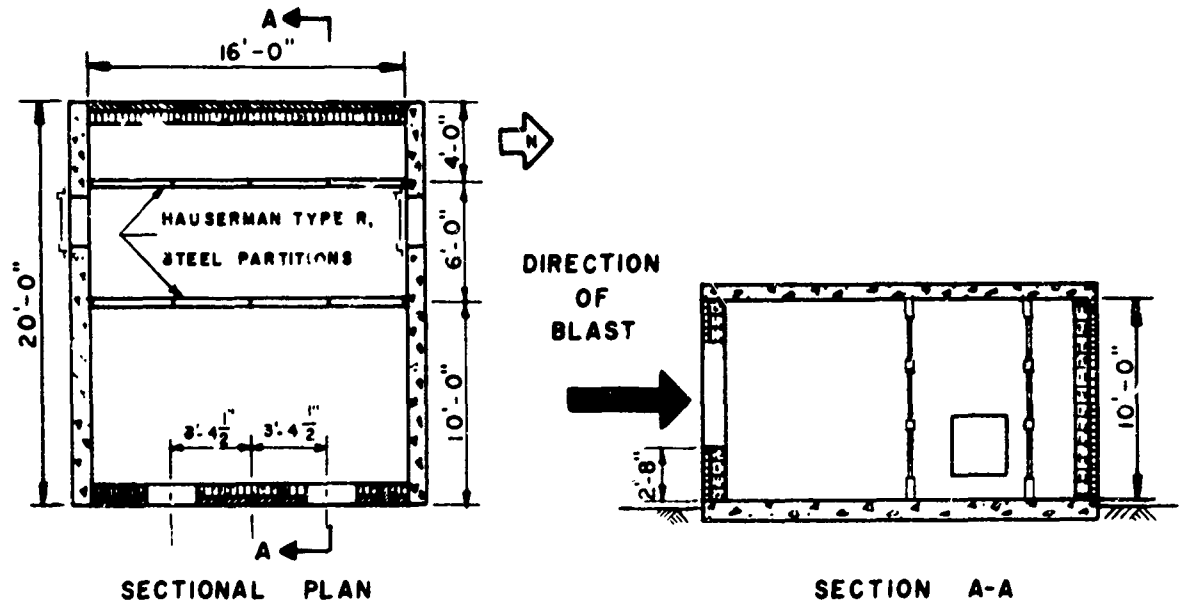


Fig. 2.180 Post Shot - Front Wall Detail  
Cell No. 5d



Fig. 2.179 Post Shot - Interior - Cell No. 5d

# CELL NO. 6d 10'x16' OPENING



## DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing and 8 in. cinder block backing. There were two windows in the front wall, 3 ft 3 in. by 5 ft 5 in. The partitions were Hauserman Type R, steel, partitions with middle section glazed. There were four nailed inserts in the end walls and five nailed inserts in the floor slab.

## CONSTRUCTION ERRORS AND OMISSIONS:

None

## FIELD DAMAGE NOTES:

The partitions were ripped loose from the floor and wall fastenings and driven against the rear wall. All partition glass was broken into fine fragments.

The front wall was bowed in 1/2 in. at the sill line, center section. The window frames were bowed in and the upper muntins were broken and blown in. The center of front wall at the top was bowed out 1/2 in.

The rear wall was bowed out 2 in. at the top, center with a hair crack running vertically from the top down halfway.

The measured, pre shot and post shot, natural frequencies of the front wall were 35.1 cps and 12.3 cps, respectively. For the rear wall, the measured, pre shot and post shot, natural frequencies were 43.6 cps and 17.2 cps, respectively.

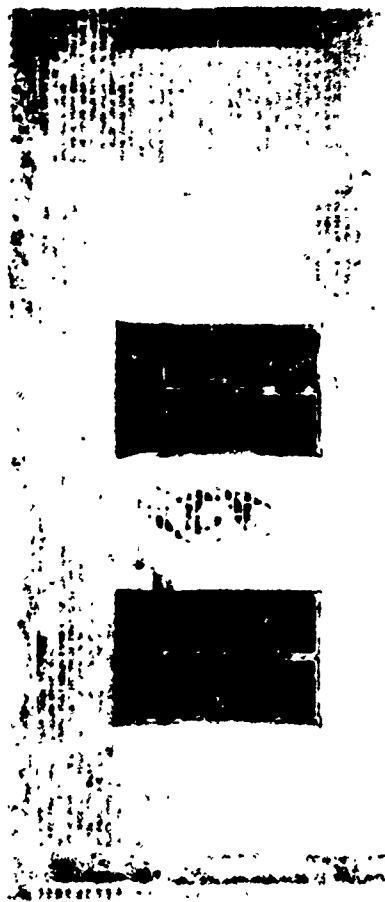


Front Wall



Rear Wall

Fig. 2.181 Pre Shot photography - Cell No. 6d



Front Wall



Rear Wall

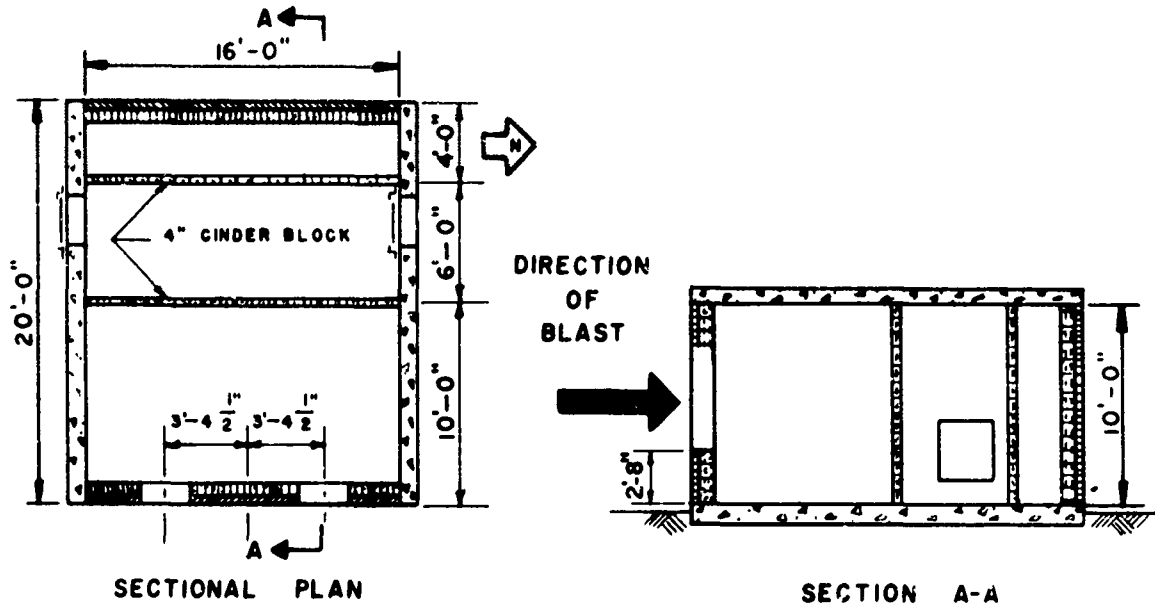
Fig. 2.182 Post Shot Photography - Cell No. 6d





Fig. 2.183 Post Shot - Interior - Cell No. 6d

# CELL NO. 7d 10'x16' OPENING



## DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing and 8 in. cinder block backing. There were two windows in the front wall, 3 ft 3 in. by 5 ft 5 in. The partitions were 4 in. cinder block with 3/4 in. plaster on each face. The partitions had angles at the top and bottom on each face, which were anchored to the roof and floor slabs. There were dovetail anchors and mortar joints at the side edges.

## CONSTRUCTION ERRORS AND OMISSIONS:

None

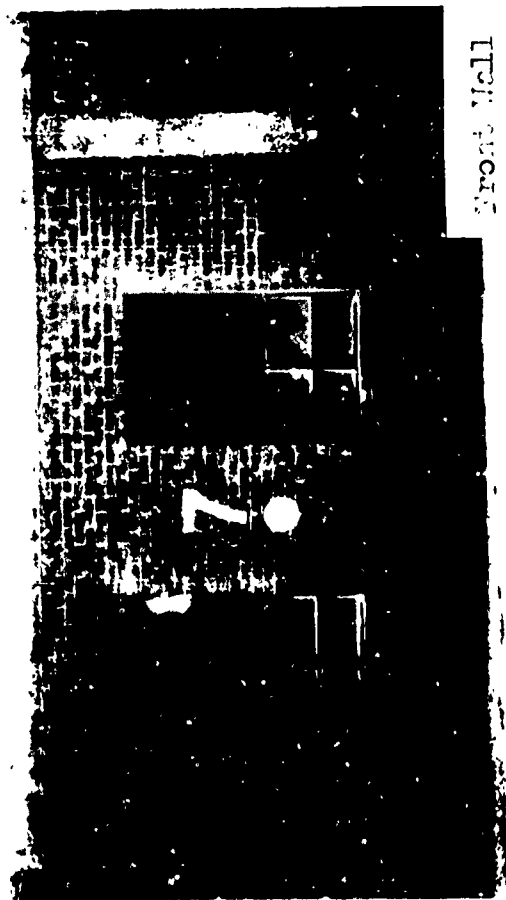
## FIELD DAMAGE NOTES:

The partitions were destroyed except for fillets and piled against the rear wall.

The front wall was cracked at the 1st and 4th mortar joint above the sill, at the center section on the inside face. The front wall was bowed in 3/4 in. at the top center and the center section was cracked at the 3rd and 12th brick course joints above the sill, on the outside face. The window frames were bowed in and the muntins broken.

The rear wall was cracked and bowed out 4 in. at the center, upper section. The outside face was broken out in the center with some brick down and cinder block showing for 5 courses at the top for 3/4 of the cell width.

The measured, pre shot and post shot, natural frequencies of the front wall were 33.7 cps and 11.2 cps, respectively. For the rear wall, the measured, pre shot, natural frequency was 55.7 cps.



Front Wall

194



Rear Wall

Fig. 2.184 Pre Shot Photography - Cell No. 7d

Fig. 2.185 Post Shot Photography - Cell No. 7d

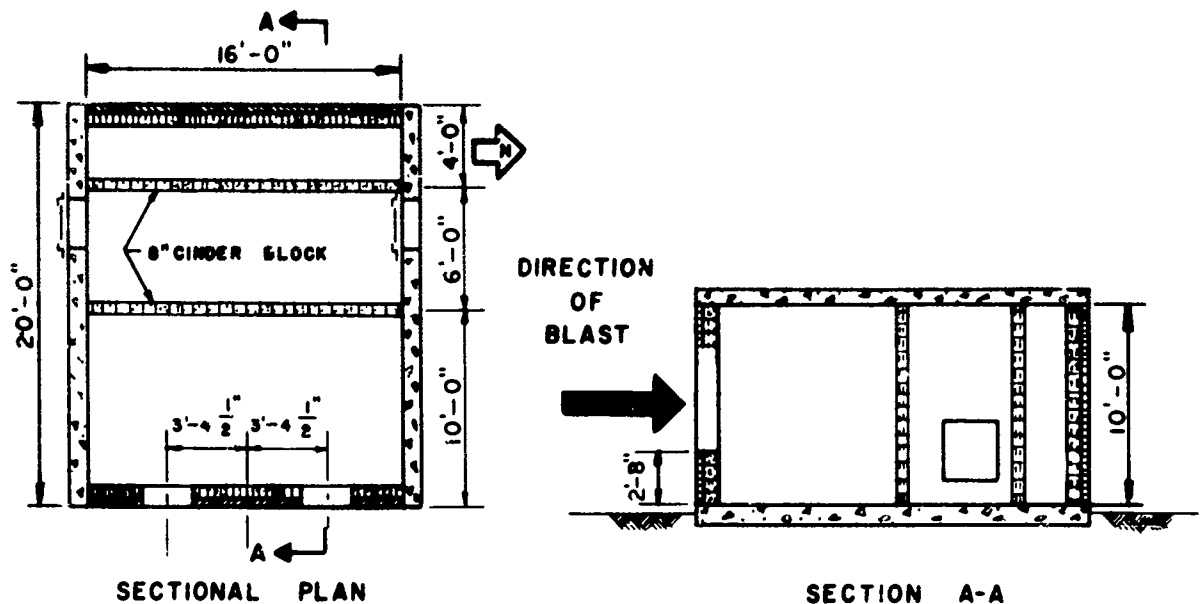


Fig. 2.186 Post Shot - Interior - Cell No. 7d



Fig. 2.187 Post Shot - Rear Wall Detail  
Cell No. 7d

# CELL NO.8d 10'x16' OPENING



## DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing and 8 in. cinder block backing. There were two windows in the front wall, 3 ft 3 in. by 5 ft 5 in. The partitions were 8 in. cinder block with 3/4 in. plaster on each face. The partitions had mortar joints at the top and bottom and dovetail anchors and mortar joints at the side edges.

## CONSTRUCTION ERRORS AND OMISSIONS:

None

## FIELD DAMAGE NOTES:

The partitions were destroyed except for 1 ft on each edge and fillets. Debris was piled up against the rear wall.

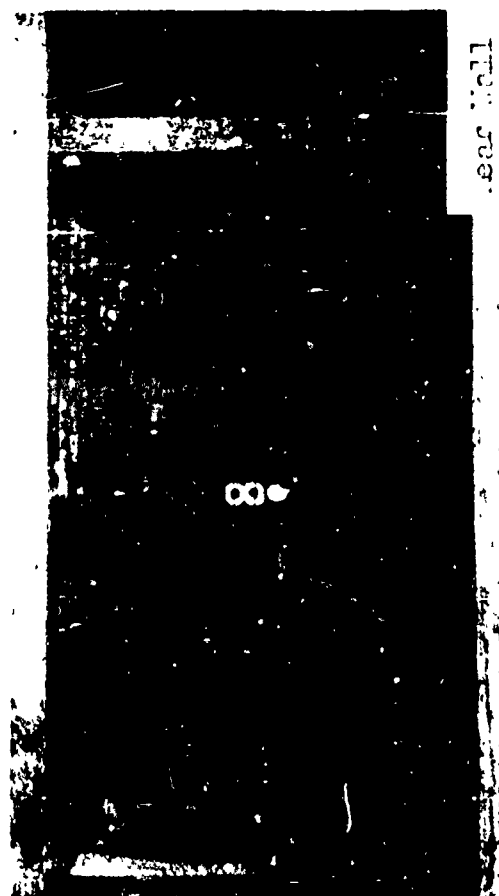
The front wall was cracked at the 4th block joint above the sill on the inside face. The inside face of the cinder block was knocked off above the north window with the lintel blown part way out. The front wall was bowed in 3/4 in. at the top center. The outside face was cracked in the center section at the sill joint and at several other courses up the front wall. The outside face was spalled along the top.

The rear wall was spalled at the top on the outside face.

The measured, pre shot and post shot, natural frequencies of the front wall were 32.7 cps and 15.8 cps, respectively. For the rear wall, the measured, pre shot and post shot, natural frequencies were 59.0 cps and 23.3 cps, respectively.

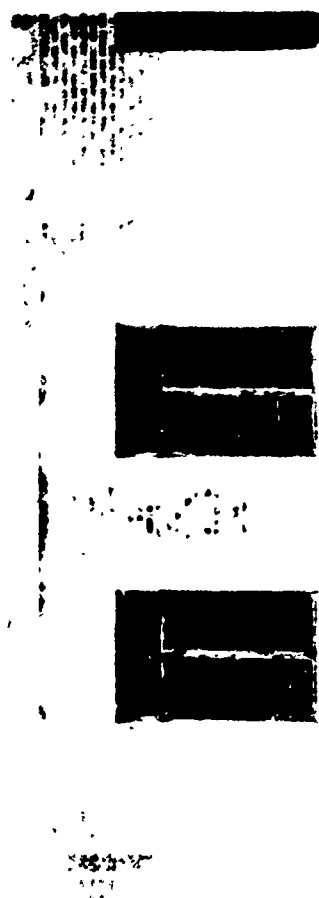


Front Wall

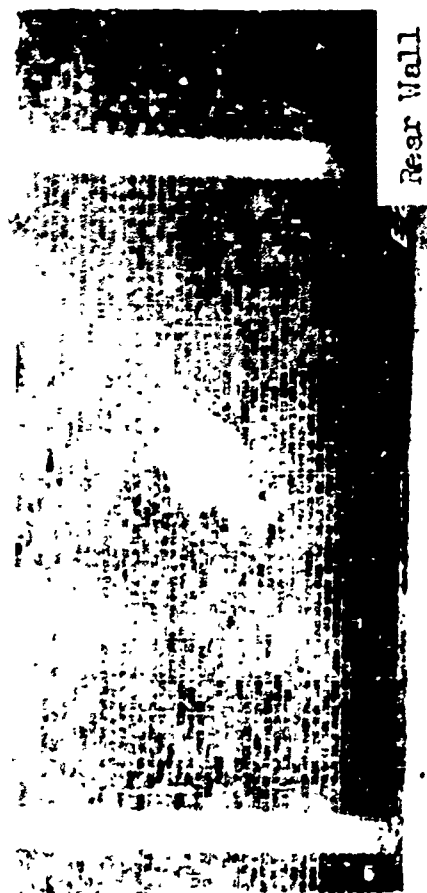


Rear Wall

Fig. 2.188 Pre Shot Photography - Cell No. 8d



Front Wall



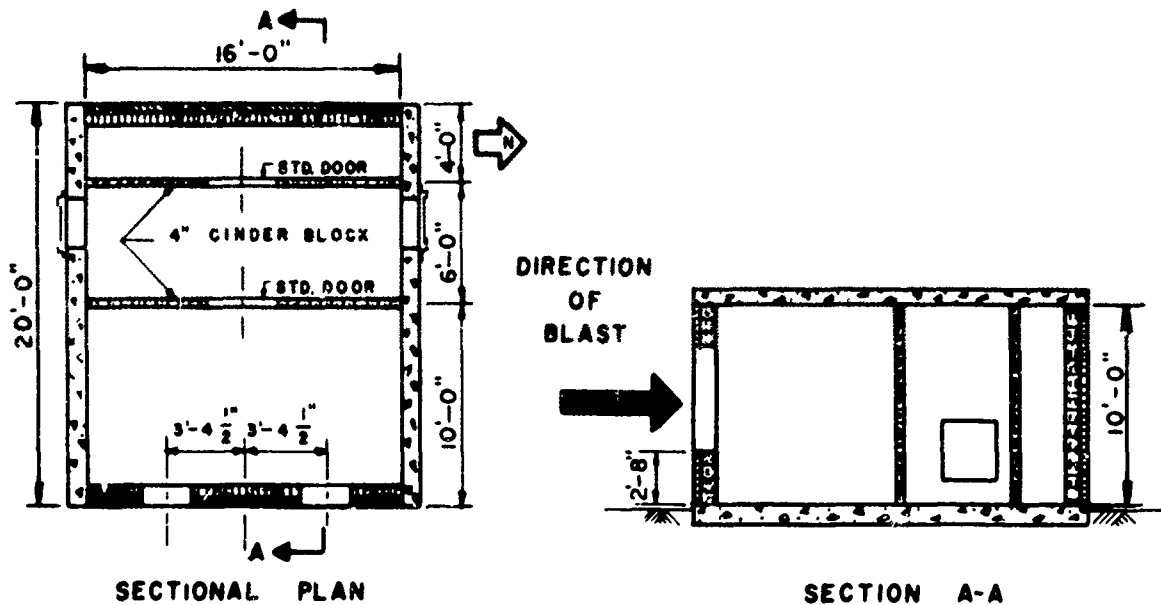
Rear Wall

Fig. 2.189 Post Shot Photography - Cell No. 8d



Fig. 2.190 Post Shot - Interior - Cell No. 8d

# CELL NO. 9d 10'x16 OPENING



## DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing with 8 in. cinder block backing. There were two windows in the front wall, 3 ft 3 in. by 5 ft 5 in. The partitions were 4 in. cinder block, with standard, 3 ft by 6 ft 8 in., doors placed in the center, and 3/4 in. plaster on each face. The partitions had mortar joints at the top and bottom and dovetail anchors and mortar joints at the side edges.

## CONSTRUCTION ERRORS AND OMISSIONS:

None

## FIELD DAMAGE NOTES:

The front partition was destroyed except for fillets and blown against the rear partition.

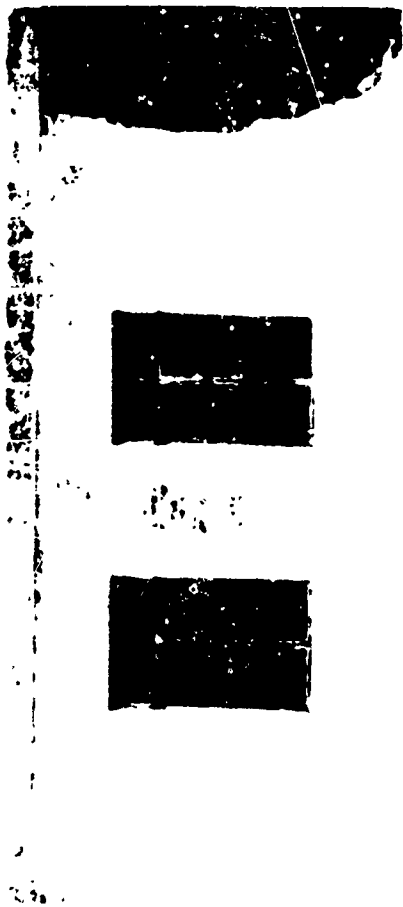
The rear partition was badly cracked and the door destroyed. There was slight displacement of the rear partition.

The front wall was cracked on the inside face just above sill and above lintel near the center. A cinder block was pushed in 2 in. at second block joint above the sill. The front wall was bowed in 1/4 in. at the top center with several minor, short cracks and spalling along the top on the outside face.

The rear wall was spalled at the top on the outside face.

The measured, pre shot and post shot, natural frequencies of the front wall were 39.2 cps and 17.0 cps, respectively. For the rear wall, the measured, pre shot and post shot, natural frequencies were 34.3 cps and 21.9 cps, respectively.





Front Wall

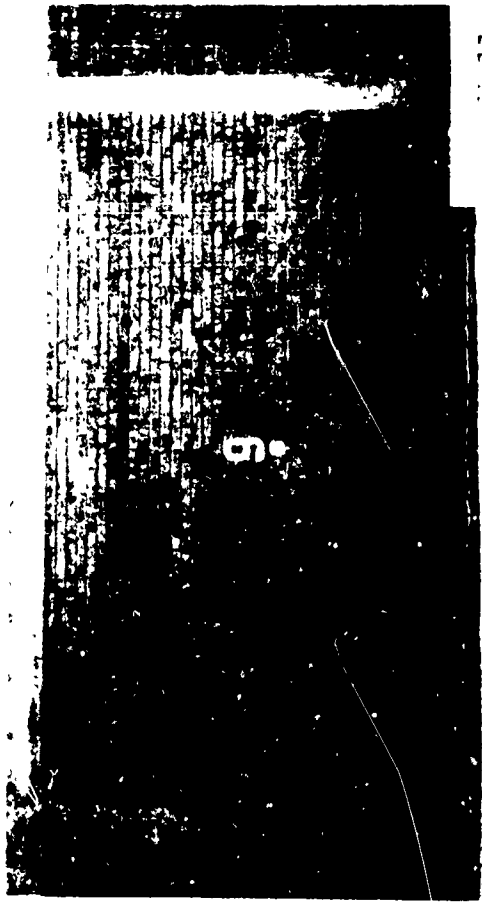


Front Wall

Fig. 2.192 Post Shot Photography - Cell No. 9d



Front Wall



Front Wall

Fig. 2.191 Pre Shot Photography - Cell No. 9d

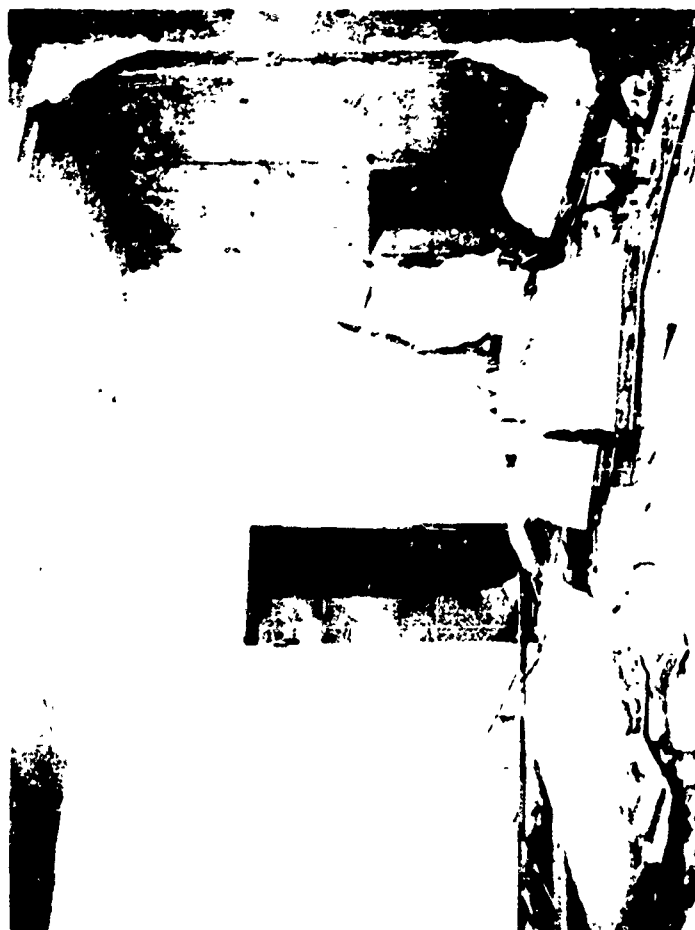
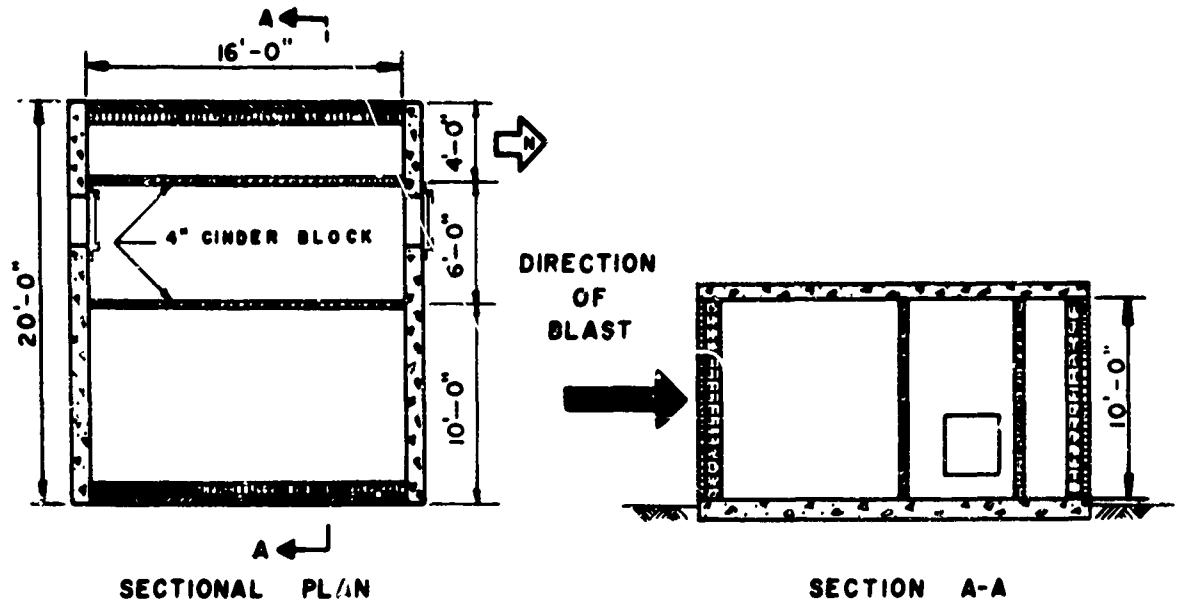


Fig. 2.193 Post Shot - Interior - Cell No. 9d

# CELL NO.10d 10'x16' OPENING



## DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing and 8 in cinder block backing. The partitions were 4 in. cinder block with 3/4 in. plaster on each face. The partitions had mortar joints at the top and bottom and dovetail anchors and mortar joints at the side edges.

## CONSTRUCTION ERRORS AND OMISSIONS:

None

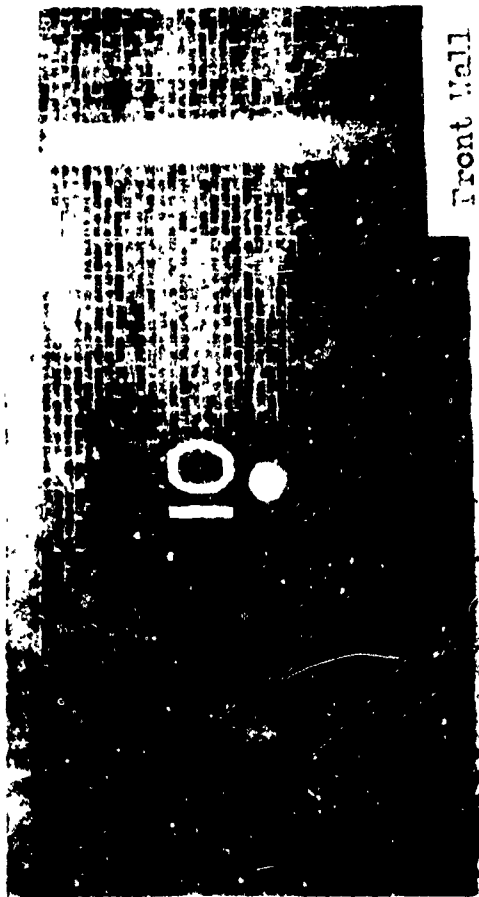
## FIELD DAMAGE NOTES:

The partitions were destroyed except for fillets and the debris piled against the rear wall.

The front wall was blown in except for 4 courses at the bottom and 1 ft at the edges plus bottom fillets.

The rear wall, at the center, had a vertical hair crack from the top down 4 courses of block. The outside face was spalled at the top.

The measured, pre shot, natural frequency of the front wall was 41.6 cps. For the rear wall, the measured, pre shot and post shot, natural frequencies were 50.0 cps and 29.7 cps, respectively.



Front Wall



Rear Wall

Fig. 2.194 Pre Shot Photography - Cell No. 10d



Front Wall



Rear Wall

Fig. 2.195 Post Shot Photography - Cell No. 10d



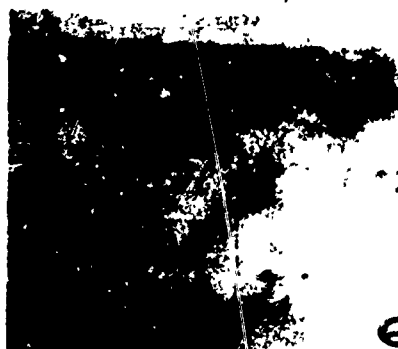
1



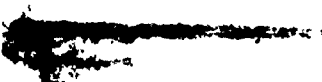
5



2



6



3



7



4

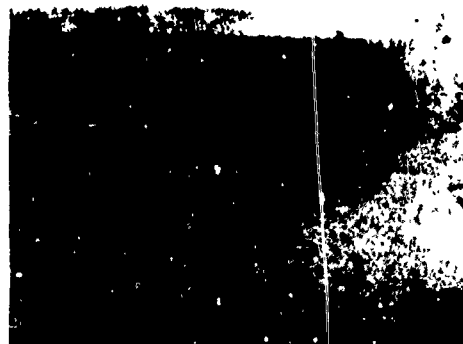
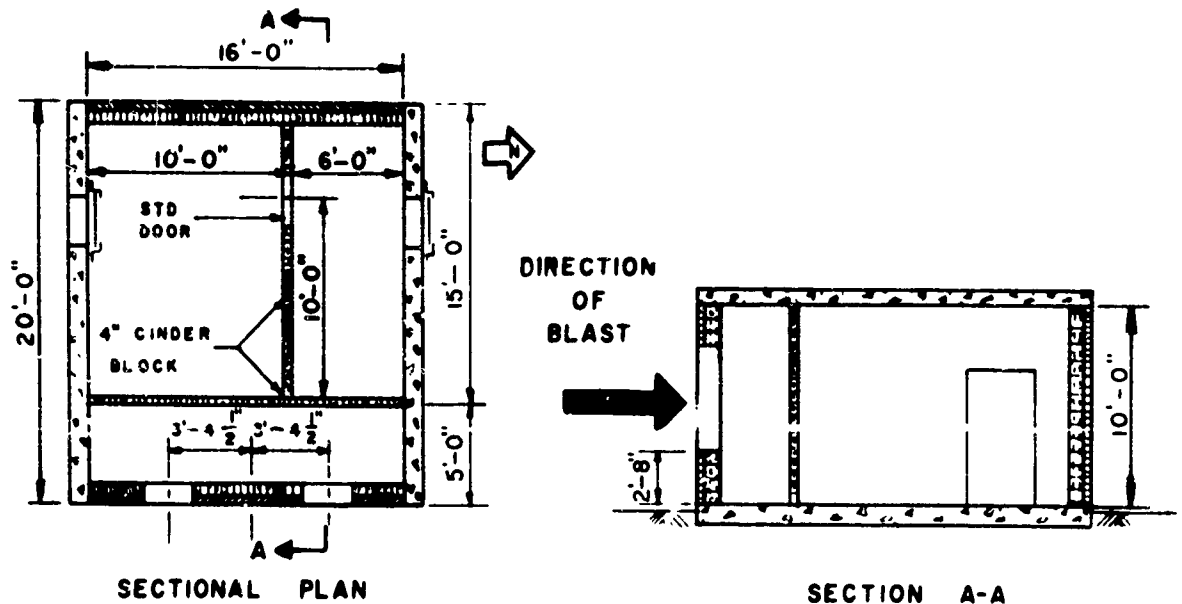


Fig 2.196 Motion Picture Sequence - Front Wall - Cell No. 10d



Fig. 2.197 Post Shot - Interior - Cell No. 104

# CELL NO. 11d 10'x16' OPENING



## DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing and 8 in. cinder block backing. There were two windows in the front wall, 3 ft 3 in. by 5 ft 5 in. The two partitions (perpendicular to each other) were 4 in. cinder block with 3/4 in. plaster on each face. The rear partition had a standard, 3 ft by 6 ft 8 in. door, near one end. The partitions had mortar joints at the top and bottom and dovetail anchors and mortar joints at the side edges.

## CONSTRUCTION ERRORS AND OMISSIONS:

None

## FIELD DAMAGE NOTES:

The front partition was completely destroyed except for fillets.

The rear partition was bowed in to the small room with horizontal cracks on both faces at 4 ft and 6 ft high. The door was blown into the small room.

The front wall was bowed in slightly at the sill line and 1/2 in. at the top. The outside face was spalled at the top and cracked across the south window. The window frames were bowed in.

The rear wall was bowed out 1/2 in. at the top. The outside face was spalled at the top. The south section of the inside face had 7 or 8 medium to large holes punched into cinder block cells.

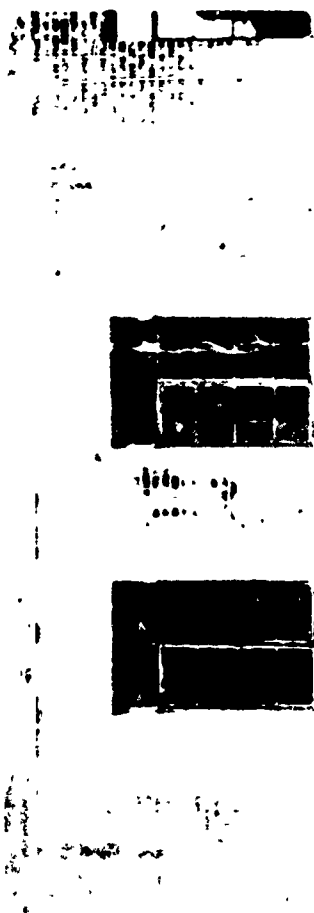
The measured, pre shot and post shot, natural frequencies of the front wall were 33.0 cps and 16.0 cps, respectively. For the rear wall, the measured, pre shot and post shot, natural frequencies were 41.6 cps and 26.3 cps, respectively.



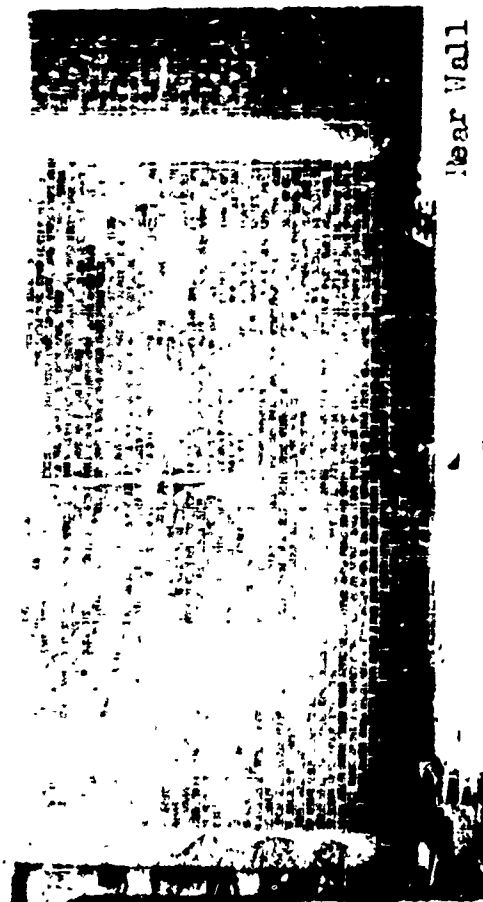
Front Wall



Rear Wall



Front Wall



Rear Wall

Fig. 2.198 Pre Shot Photography - Cell No. 11d

Fig. 2.199 Post Shot Photography - Cell No. 11d





Fig. 2.200 Post Shot - Interior - Cell No. 11d

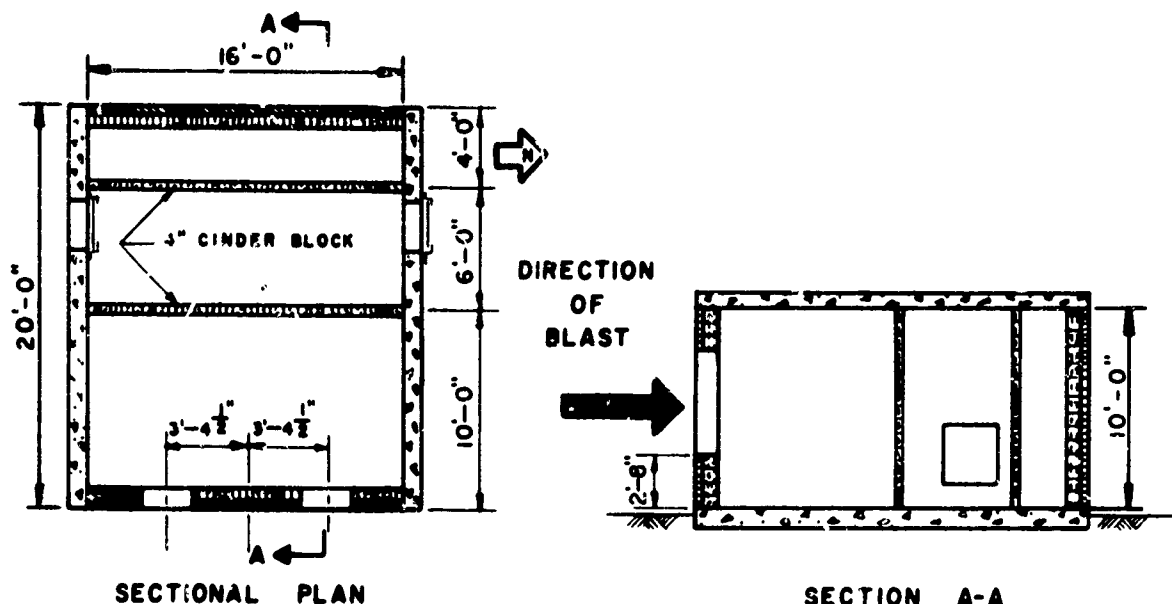


Fig. 2.202 Post Shot - Interior  
Small Room - Cull No. 11d



Fig. 2.201 Post Shot - Interior - Cell No. 11d

# CELL NO.12d 10'x16' OPENING



## DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing and 8 in. cinder block backing. There were two windows in the front wall, 3 ft 3 in. by 5 ft 5 in. The partitions were 4 in. cinder block with 3/4 in. plaster on each face. The partitions had mortar joints at the top and bottom and dovetail anchors and mortar joints at the side edges.

## CONSTRUCTION ERRORS AND OMISSIONS:

None

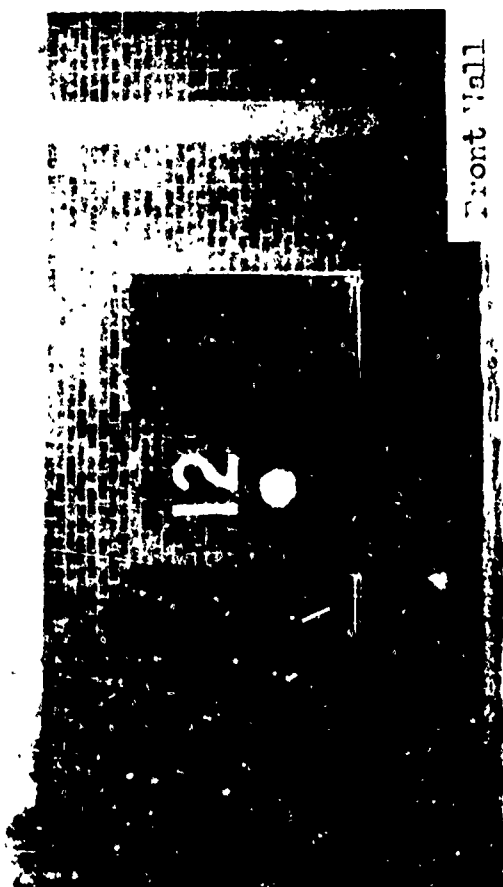
## FIELD DAMAGE NOTES:

The partitions were destroyed except for fillets.

The front wall was bowed in 1/2 in. at the top center. The center section was bowed in 1/8 in. to 1/4 in. at the sill line. The outside face, center section, had a crack along the sill line. Some other minor cracking and spalling was shown on the outside face. The window frames were bowed in. The inside face had a cinder block over the north window broken off. The lintels were blown part of the way out on the inside face.

The rear wall was blown out except for 1 ft at the south edge and 5 ft of cinder block and larger area of brick wall at the north edge. The debris was piled 5 ft high behind the front partition.

The measured, pre shot and post shot, natural frequencies of the front wall were 35.5 cps and 19.5 cps, respectively. For the rear wall, the measured, pre shot, natural frequency was 44.4 cps.

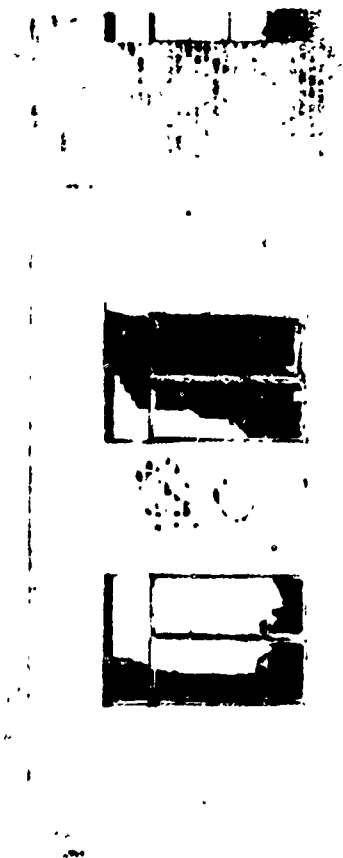


Front Wall

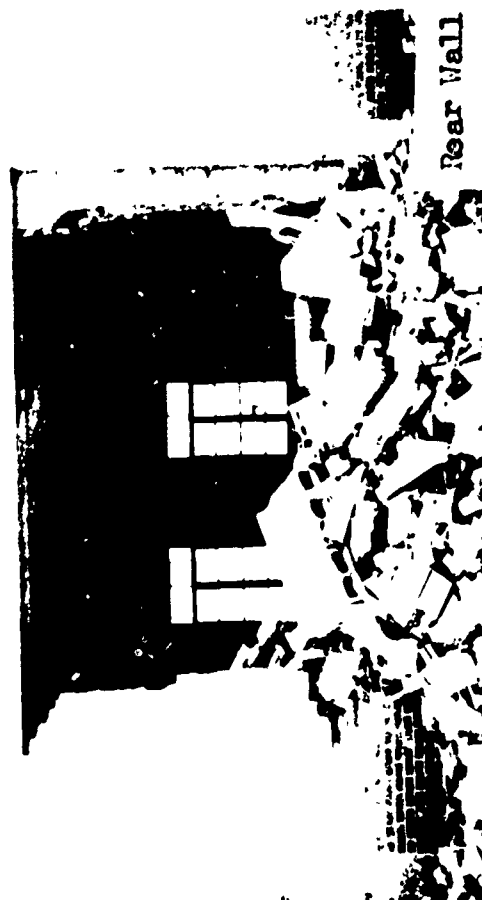


Rear Wall

Fig. 2.203 Pre Shot Photography - Cell No. 12d



Front Wall



Rear Wall

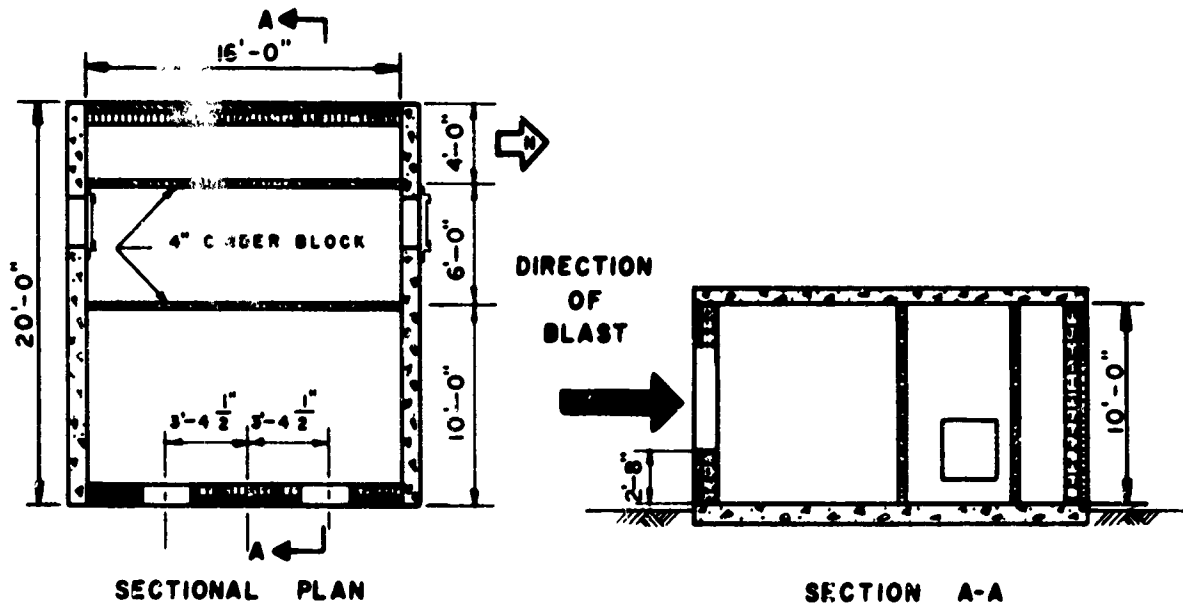
Fig. 2.204 Post Shot Photography - Cell No. 12d



Fig. 2.206 Post Shot - Rear Wall Detail  
Cell No. 12d

Fig. 2.205 Post Shot - Interior - Cell No. 12d

### CELL NO.13d 10' x16' OPENING



#### DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing and 8 in. cinder block backing. There were two windows in the front wall, 3 ft 3 in. by 5 ft 5 in. The partitions were 4 in. cinder block with 3/4 in. plaster on each face. The partitions had mortar joints at the top and bottom and dovetail anchors and mortar joints at the side edges.

#### CONSTRUCTION ERRORS AND OMISSIONS:

Dovetail anchors should not have been used at the side edges of the partitions.

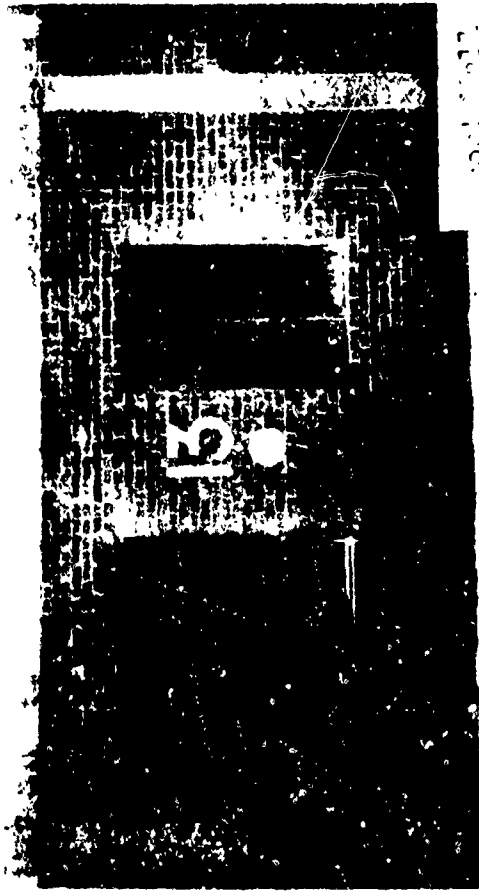
#### FIELD DAMAGE NOTES:

The partitions were destroyed except for fillets.

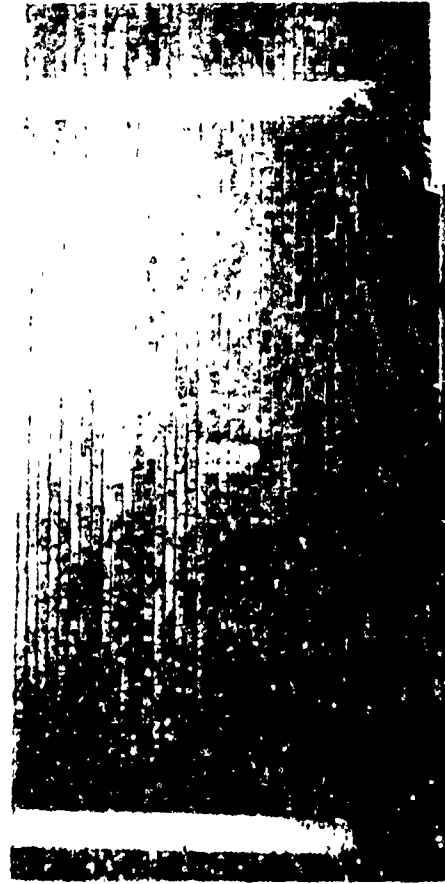
The front wall was bowed out in the center, 3/8 in. The center section was cracked, on the outside face, at the sill line and bowed in 1/8 in. The outside face was spalled at the top and had minor cracking at the upper corners of the windows. The inside face was cracked at the 2nd and 4th block in the center section and had a diagonal crack in the cinder block above the southern window.

The rear wall was blown out except for 1 ft at the edges.

The measured, pre shot and post shot natural frequencies of the front wall were 34.4 cps and 18.6 cps, respectively. For the rear wall, the measured, pre shot, natural frequency was 55.4 cps.

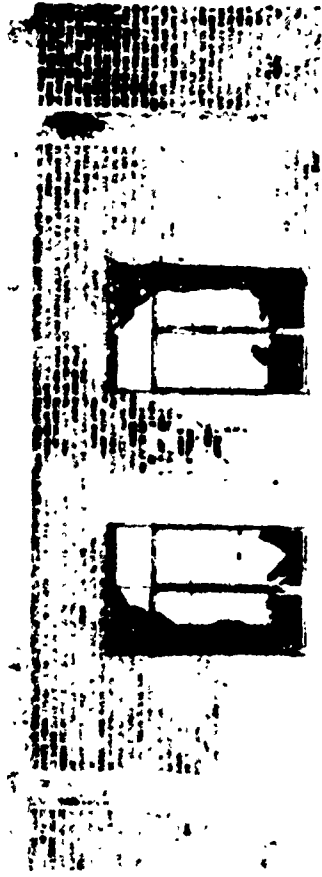


Front Wall

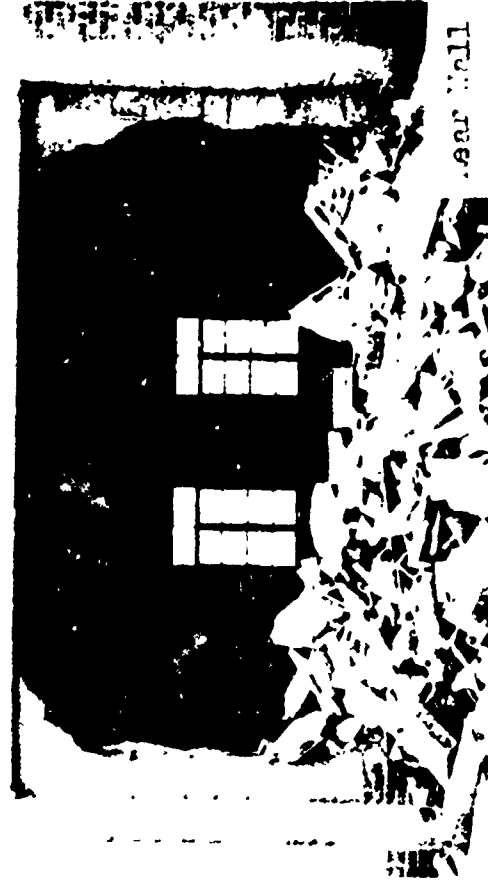


Front Wall

Fig. 2.207 Pre Shot Photography - Cell No. 134



Front Wall



Front Wall

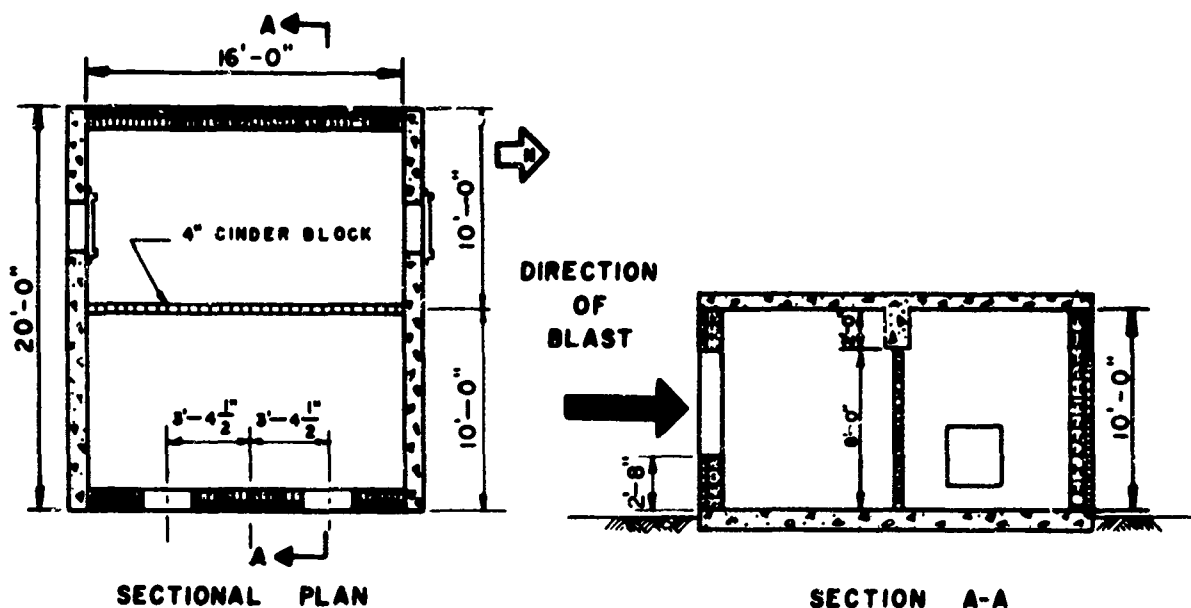
Fig. 2.208 Post Shot Photography - Cell No. 134



Fig. 2.209 Post Shot - Interior - Cell No. 13d



# CELL NO.14d 10'x16' OPENING



## DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing and 8 in. cinder block backing. There were two windows in the front wall, 3 ft 3 in. by 5 ft 5 in. The partition was 4 in. cinder block with 3/4 in. plaster on each face. The partition had mortar joints at the top and bottom and dovetail anchors and mortar joints at the side edges.

## CONSTRUCTION ERRORS AND OMISSIONS:

None

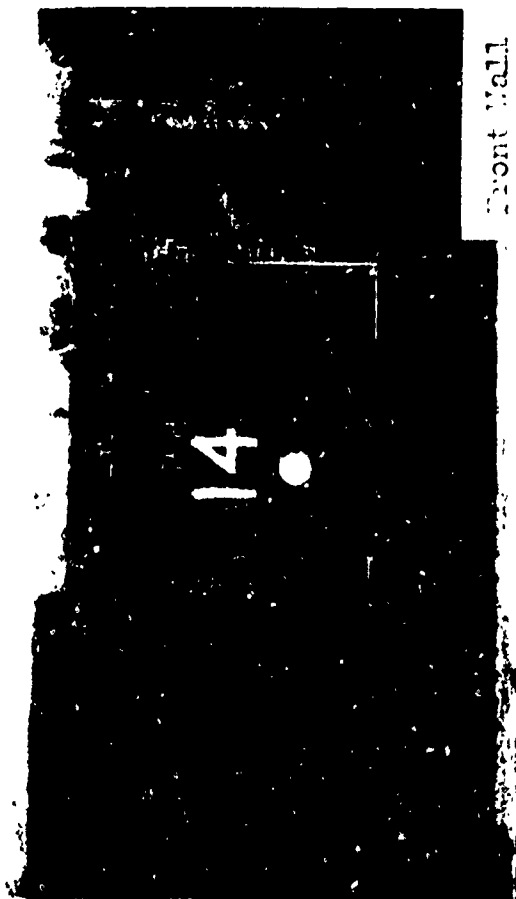
## FIELD DAMAGE NOTES:

The partition was destroyed, except for fillets, and blown against the rear wall.

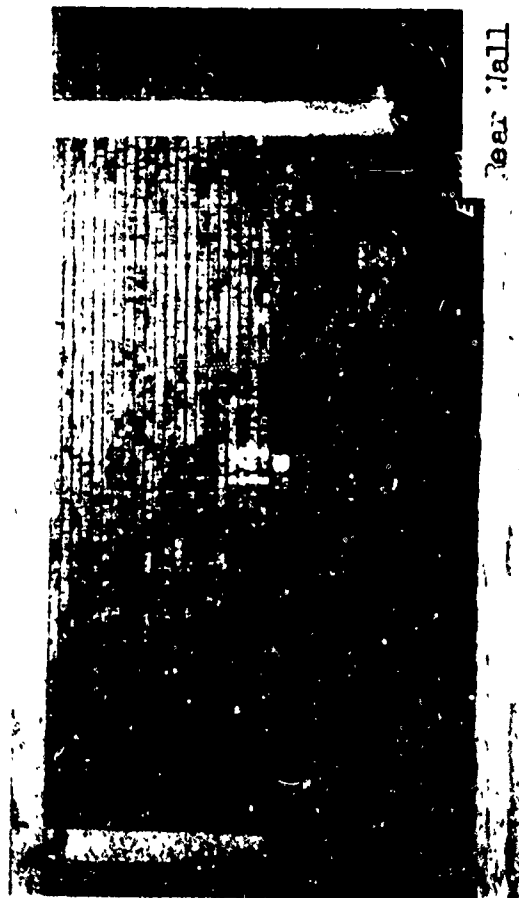
The front wall was bowed in 1-1/4 in. at the top and 1/2 in. at the sill line, center section. There were several horizontal joint cracks across the center section and other cracks in the front wall. The outside face had a crack at the sill line of the center section and diagonal cracking at the upper sections of the windows.

The rear wall was bowed out 3/8 in. at the top and bottom. The rear wall was spalled all around on the outside face with numerous medium size holes punched into the cinder block cells on the inside face.

The measured, pre shot and post shot, natural frequencies of the front wall were 33.3 cps and 14.3 cps, respectively. For the rear wall, the measured, pre shot and post shot, natural frequencies were 37.5 cps and 24.9 cps respectively.



Front Wall



Rear Wall

Fig. 2.210 Pre Shot Photography - Cell No. 14d



Front Wall



Rear Wall

Fig. 2.211 Post Shot Photography - Cell No. 14d

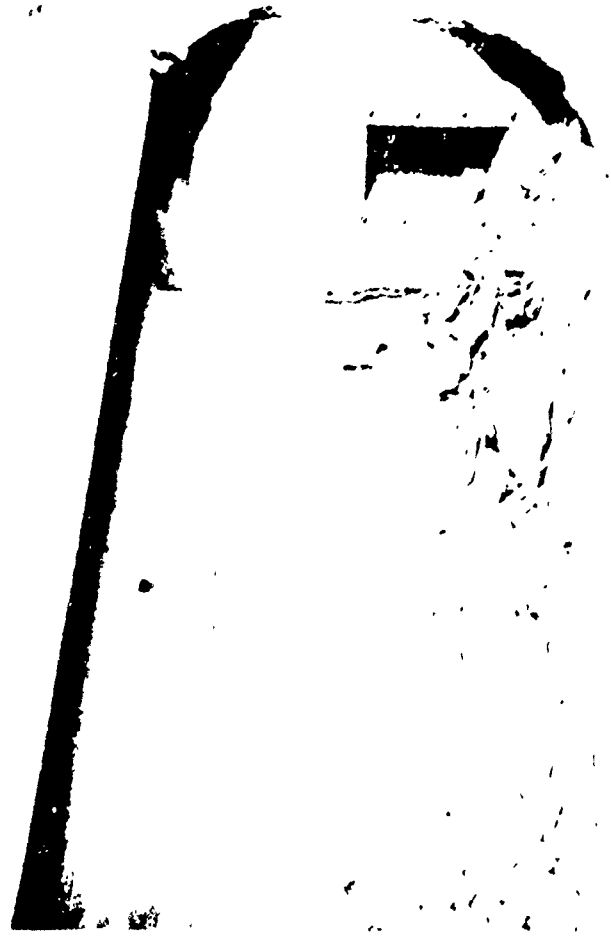
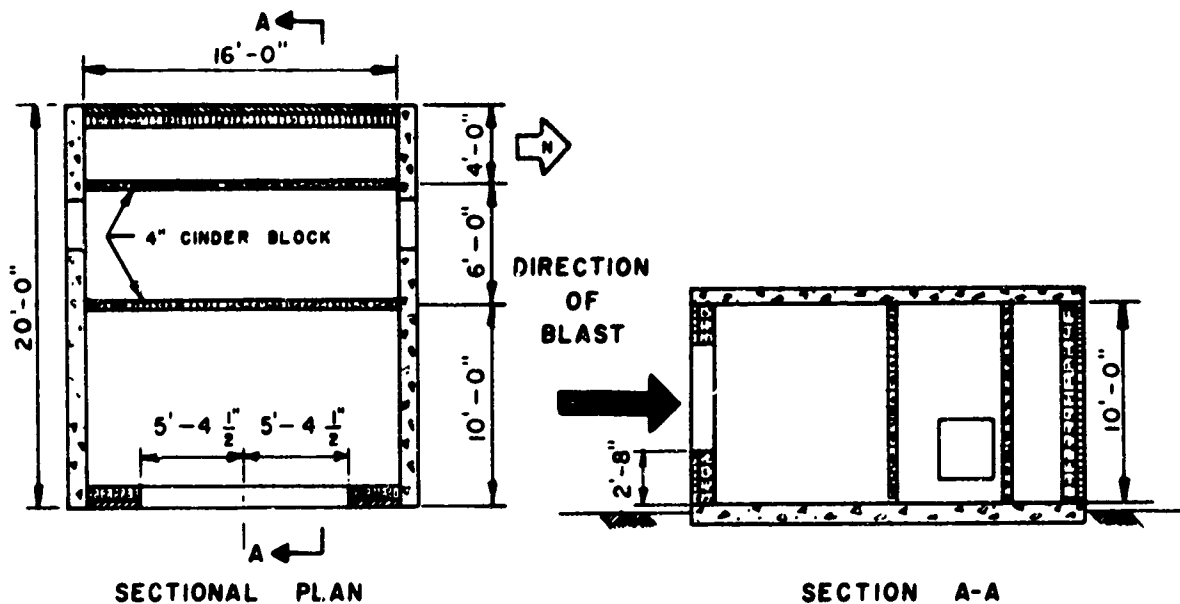


Fig. 2.212 Post Shot - Interior - Cell No. 14d

# CELL NO.15d 10'x16' OPENING



## DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing and 8 in. cinder block backing. There was one window in the front wall, 5 ft 5 in. by 10 ft 9 in. The partitions were 4 in. cinder block with 3/4 in. plaster on each face. The partitions had mortar joints at the top and bottom and dovetail anchors and mortar joints at the side edges.

## CONSTRUCTION ERRORS AND OMISSIONS:

None

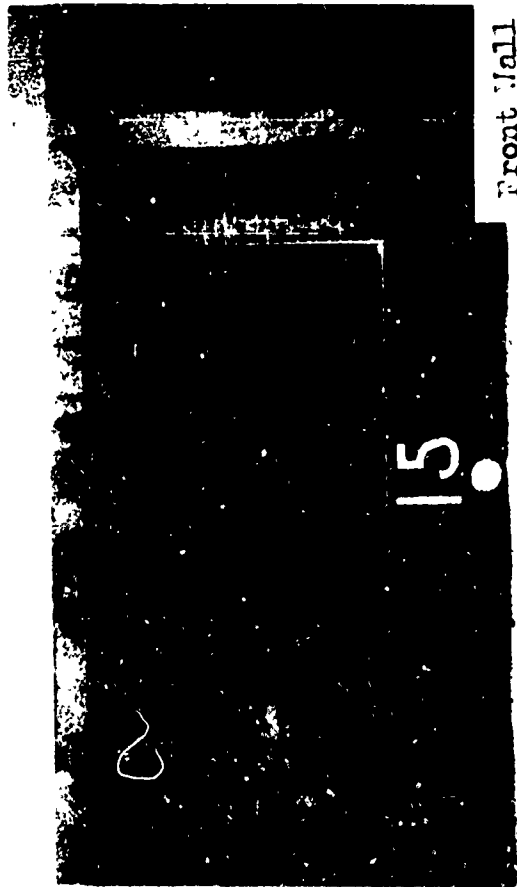
## FIELD DAMAGE NOTES:

The partitions were destroyed except for fillets.

The front wall was bowed in 1/4 in. at the top and bottom with a vertical crack in the center, above and below the window. The window was broken into 3 sections and blown into the cell with the inner angle of the lintel blown down.

The rear wall was blown out except for 1 ft at the edges.

The measured, pre shot, natural frequency of the rear wall was 51.9 cps.

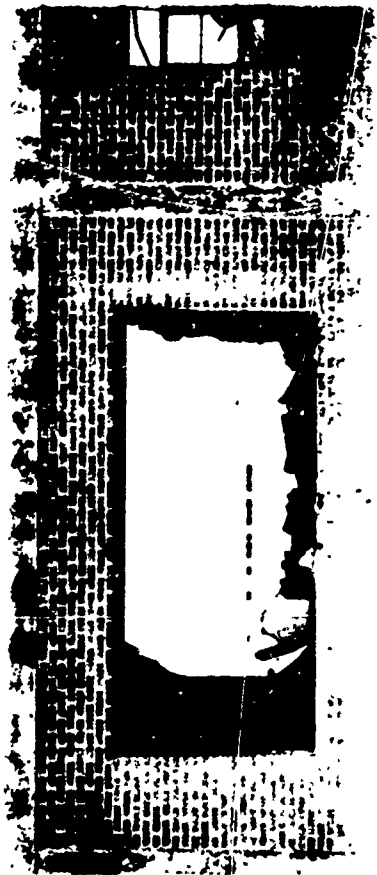


Front Wall



Rear Wall

Fig. 2.213 Pre Shot Photography - Cell No. 15d



Front Wall



Rear Wall

Fig. 2.214 Post Shot Photography - Cell No. 15d

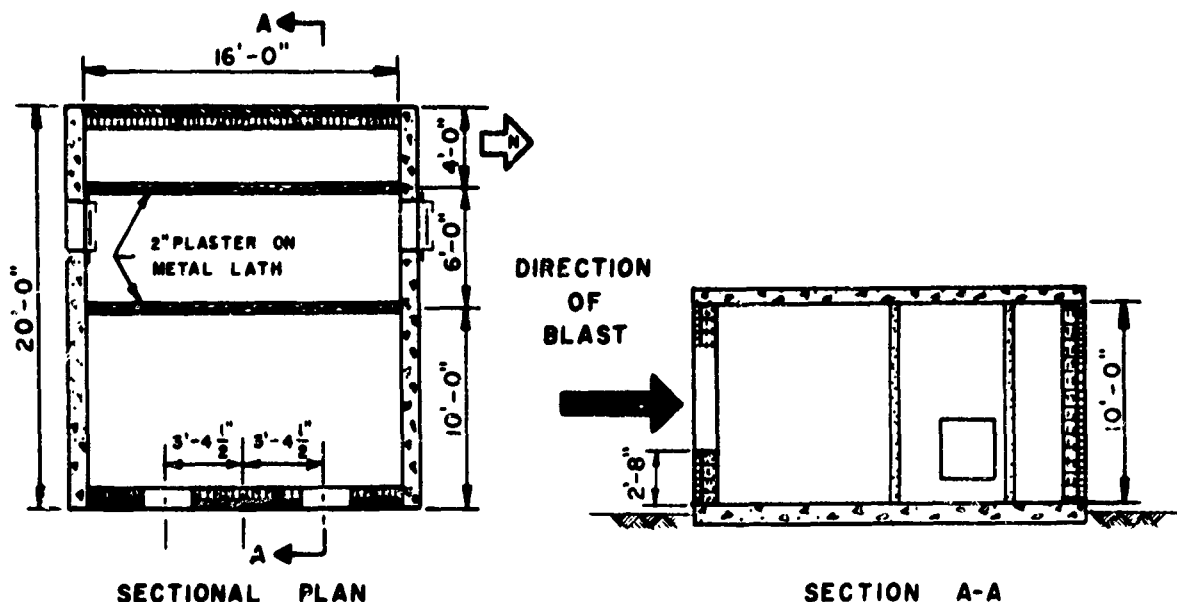


Fig. 2.215 Post Shot - Interior - Cell No. 15d



Fig. 2.216 Post Shot - Interior - Cell No. 15d

# CELL NO. 16d 16'x16' OPENING



## DESCRIPTION:

The front and rear walls consisted of 4 in. brick facing and 8 in. cinder block backing. There were two windows in the front wall, 3 ft 3 in. by 5 ft 5 in. The partitions were 2 in. plaster on metal lath attached to 1 in. x 1 in. x 3/16 in. angles which were secured to the floor and roof slabs with 3/8 in. round expansion bolts at 2 ft on centers.

## CONSTRUCTION ERRORS AND OMISSIONS:

The 1 in. x 1 in. x 3/16 in. angles at the side edges of the partitions were not installed.

## FIELD DAMAGE NOTES:

The partitions were torn loose and blown thru the cell.

The front wall was bowed in 1/2 in. at the top center. The window frames were bowed in. The outside face was cracked at the 5th mortar joint above the sill line, in the center section. The inside face was bowed into the cell 1/2 in. at the 2nd mortar course above the sill line, with the cinder block separated from the brick.

The rear wall was blown out except for 1 ft at the edges.

The measured, pre shot and post shot, natural frequencies of the front wall were 37.5 cps and 30.6 cps, respectively. For the rear wall, the measured, pre shot, natural frequency was 50.8 cps.

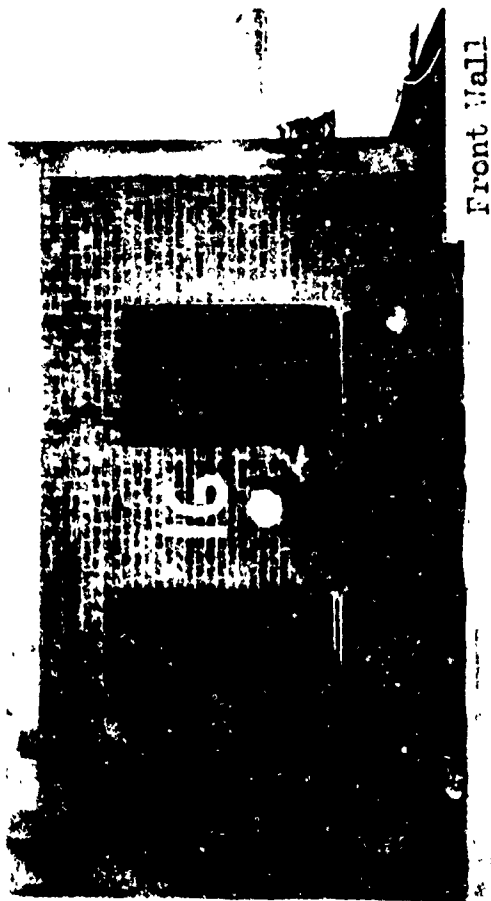


Fig. 2.217 Pre Shot Photography - Cell No. 16d

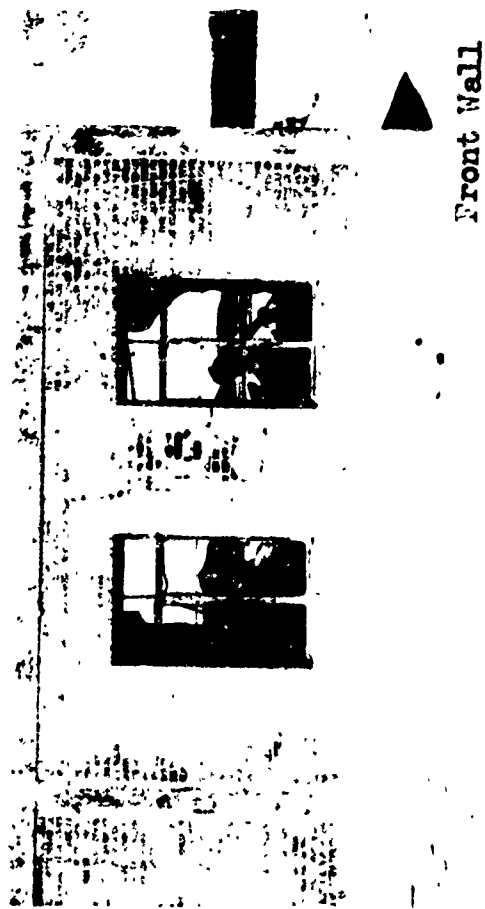


Fig. 2.218 Post Shot Photography - Cell No. 16d





Fig. 2.219 Post Shot - Floor Detail - Cell No. 16a



Fig. 2.220 Post Shot - Interior - Cell No. 16d



Fig. 2.221 Post Shot - Ceiling Detail - Cell No. 16d

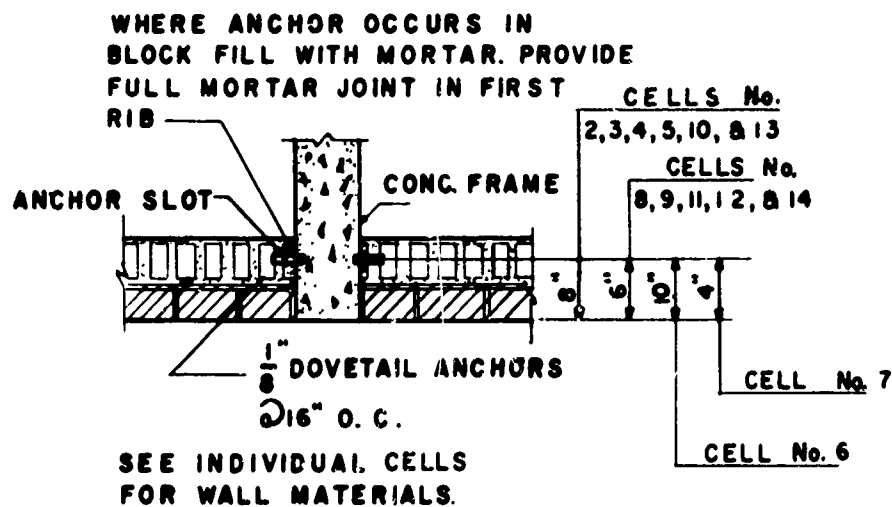


Fig. 2.222 Corner Detail for Front and Rear Wall  
Bldgs. 3.29a & 3.29c

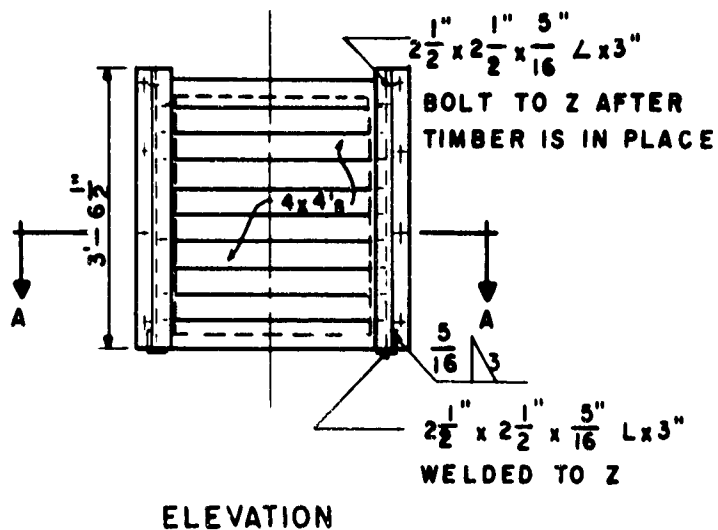
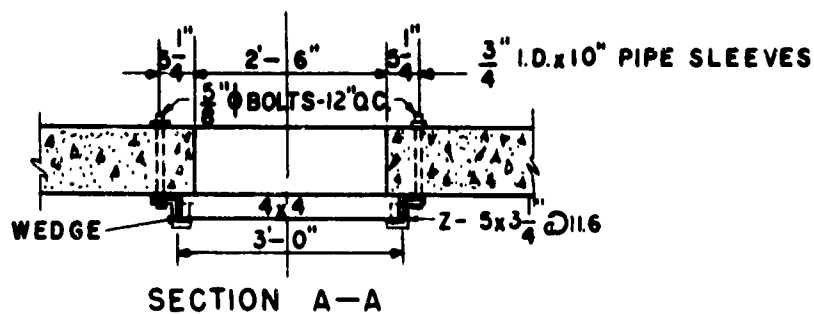


Fig. 2.223 Closure Detail for Cell Openings  
Bldgs. 3.29a, 3.29b, 3.29c & 3.29d



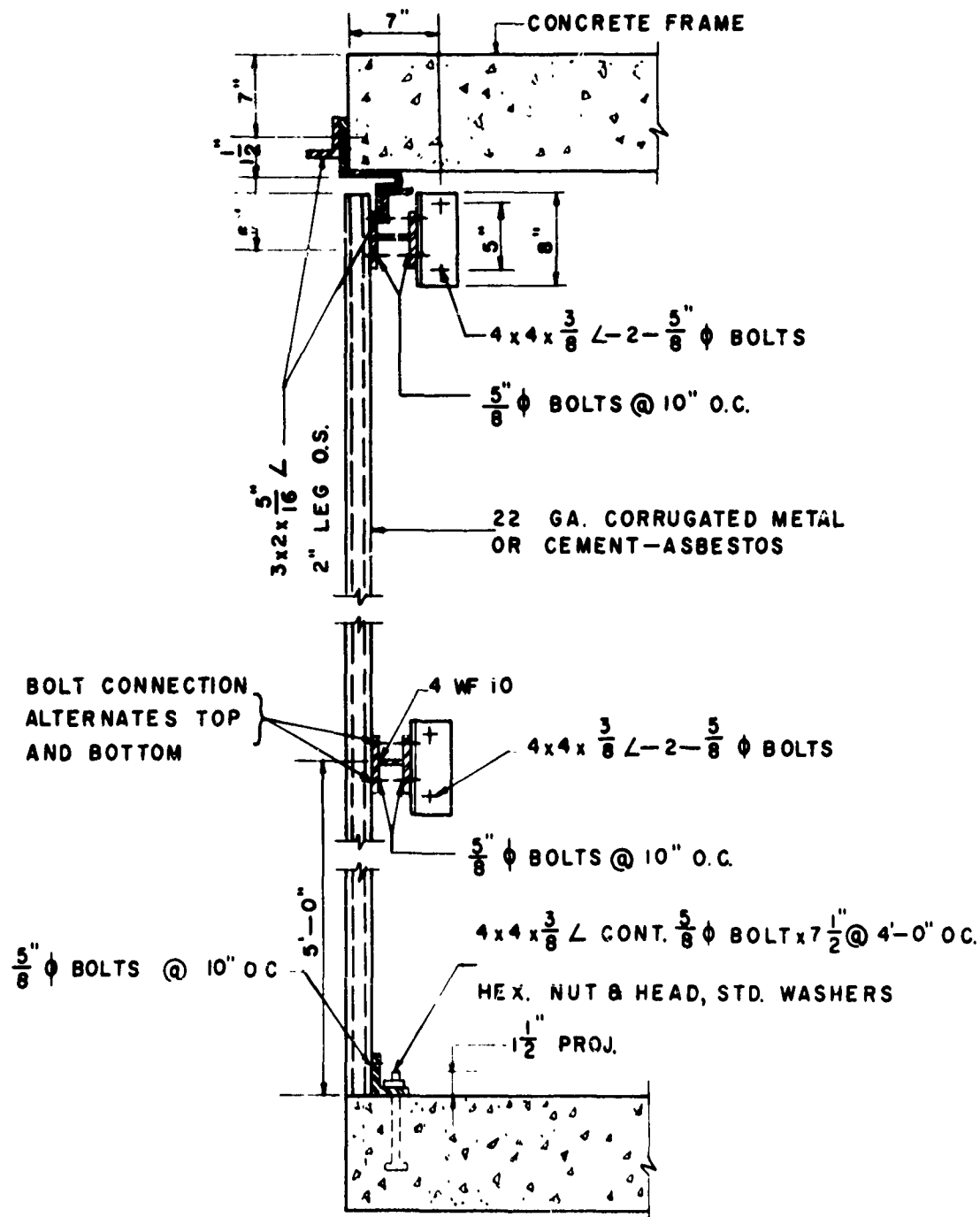


Fig. 2.226 Rear Wall Detail for Cells No. 16 & 17  
Bldgs. 3.29a & 3.29c

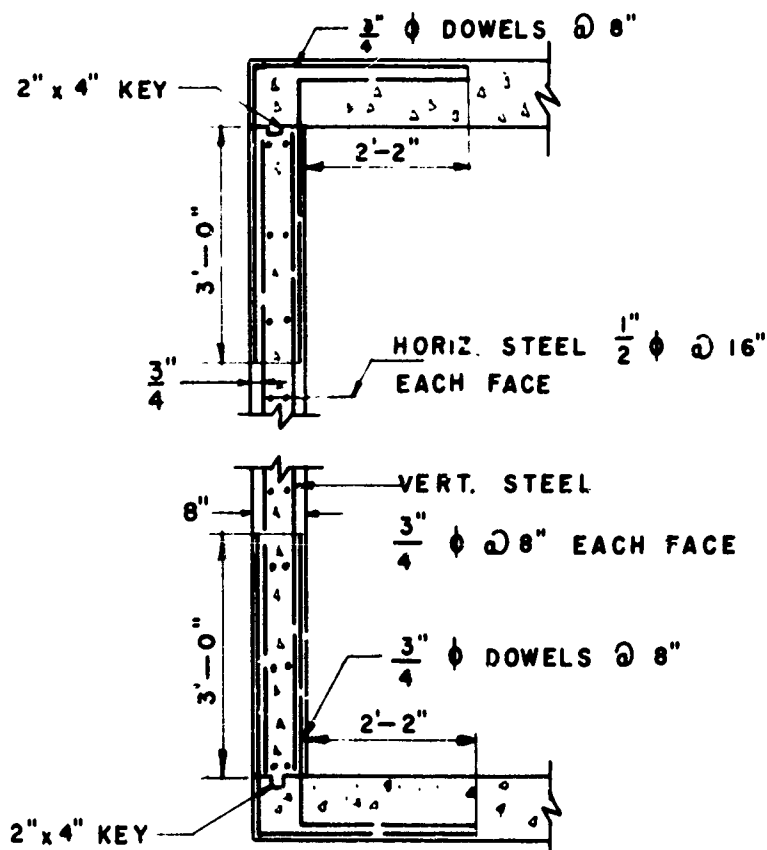


Fig. 2.227 Front and Rear Wall Detail for Cell No. 14  
Bldgs. 3.29a & 3.29c

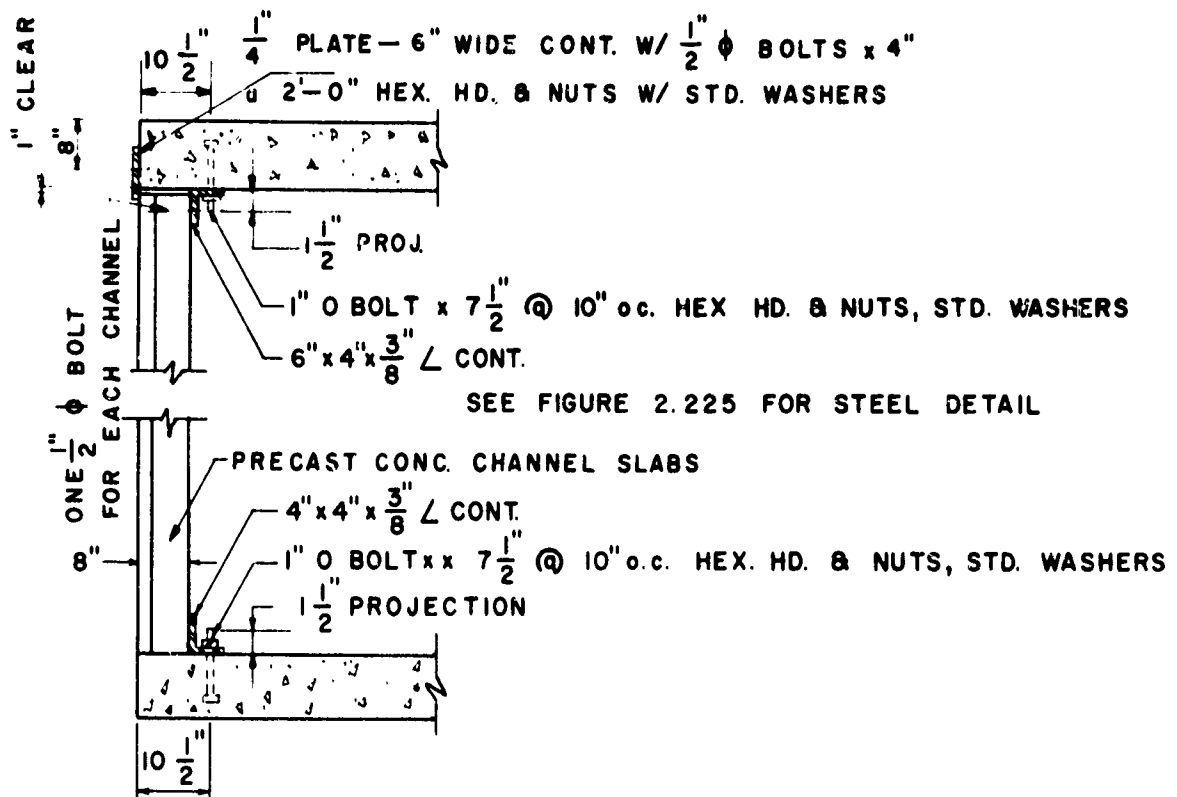


Fig. 2.228 Rear Wall Detail for Cell No. 18  
Bldgs. 3.29a & 3.29c

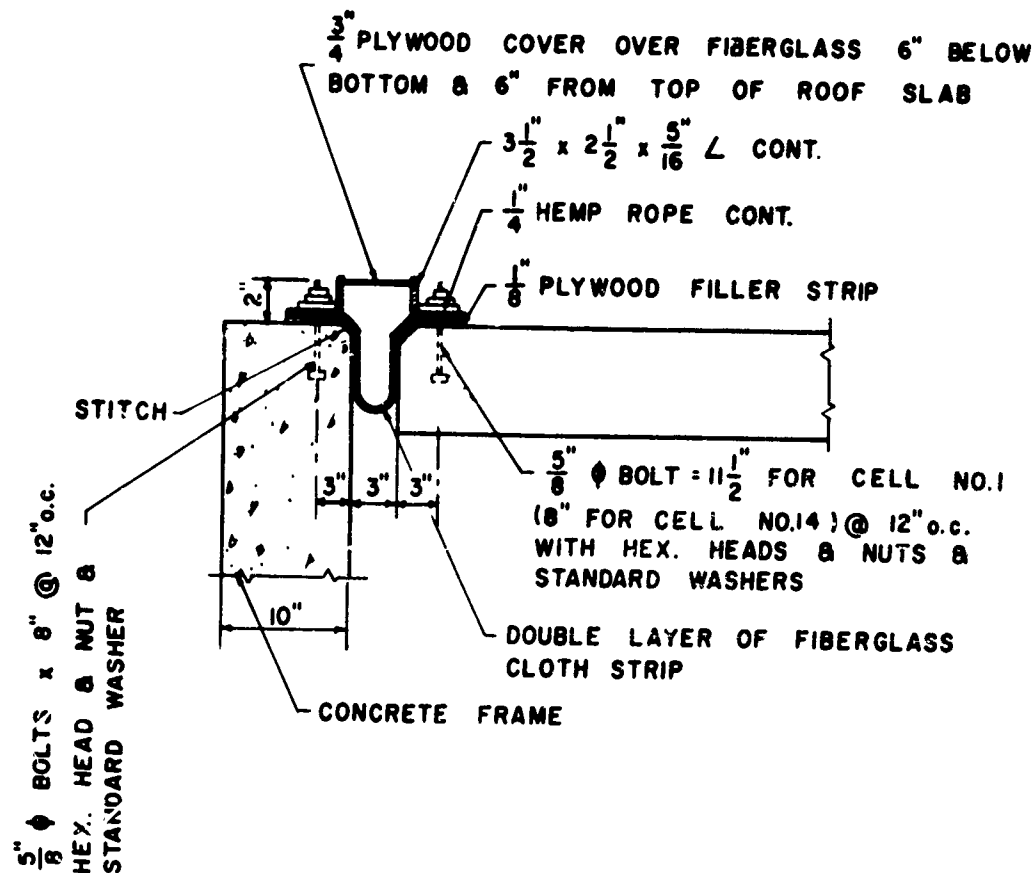


Fig. 2.229 Corner Detail for Cells No. 1 & 14 - Front and Rear Walls - Bldgs. 3.29a & 3.29c

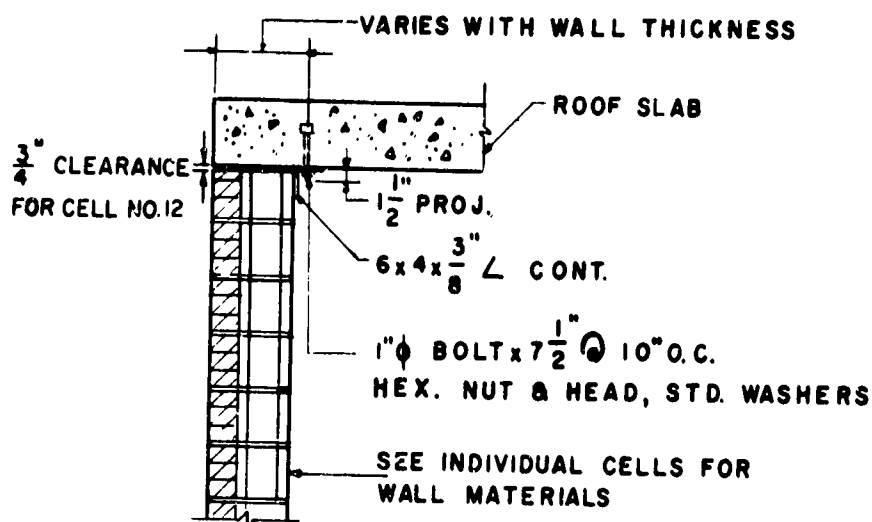


Fig. 2.230 Top Joint Detail (Bottom Similar) for Cells No. 5, 10, & 12 - Front and Rear Walls - Bldgs. 3.29a & 3.29c

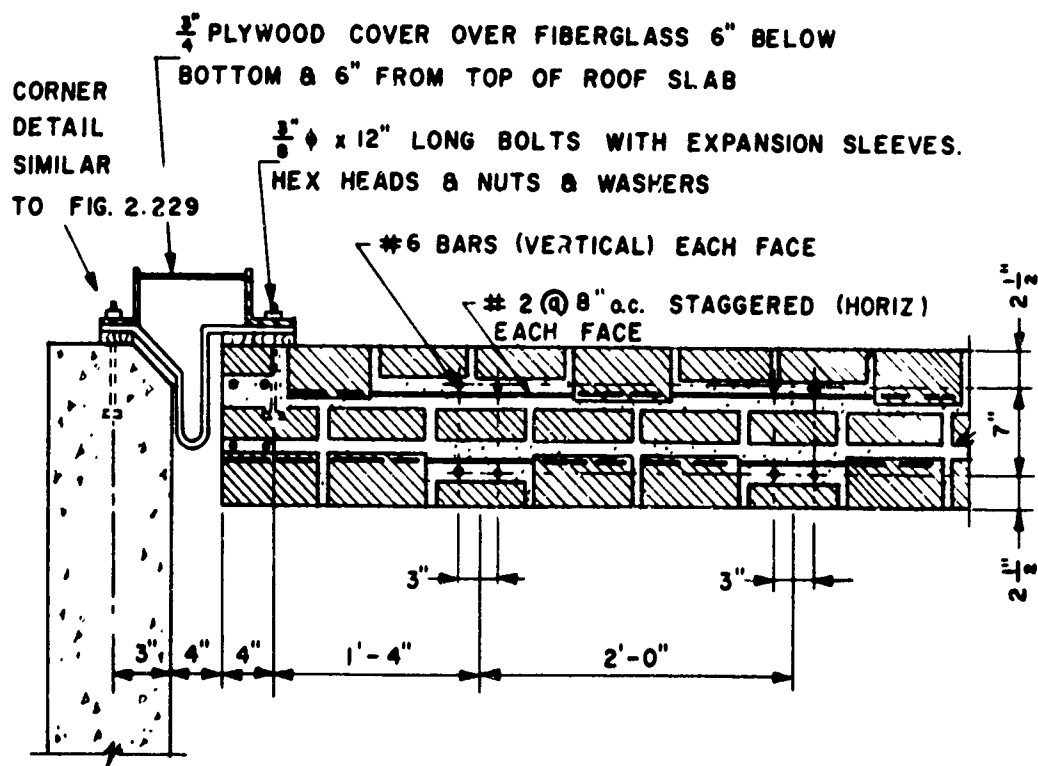


Fig. 2.231 Corner and Front Wall Detail for Cell No. 15  
Bldg. 3.29c

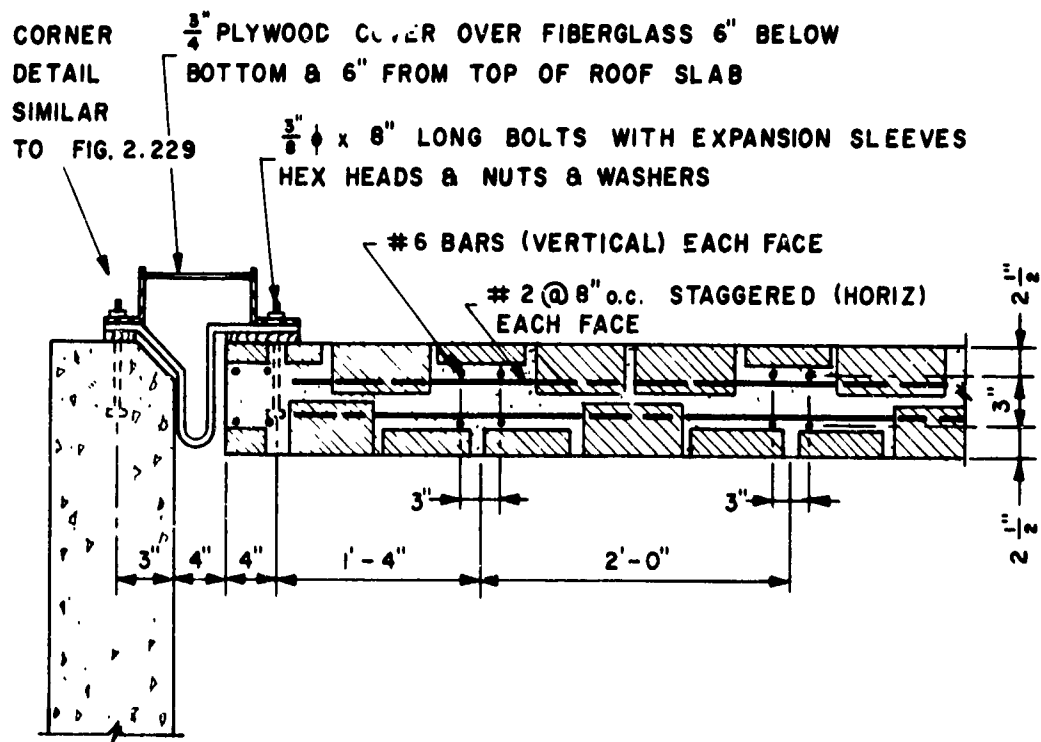


Fig. 2.232 Corner and Rear Wall Detail for Cell No. 15  
Bldgs. 3.29a & 3.29c



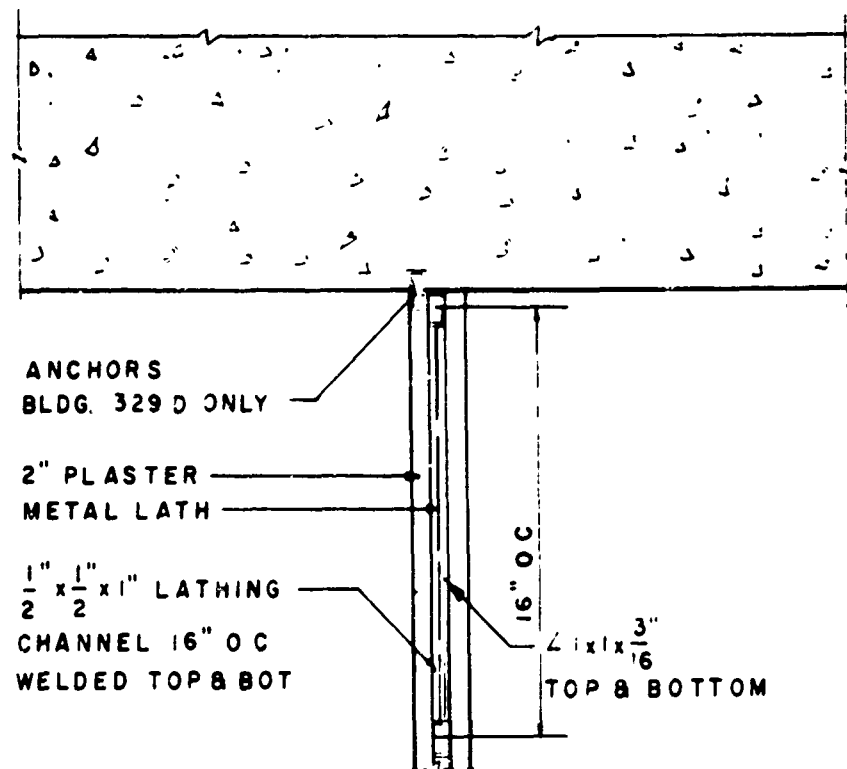


Fig. 2.233 Corner Detail for Partitions - Cell No. 16  
Bldgs. 3.29b & 3.29d

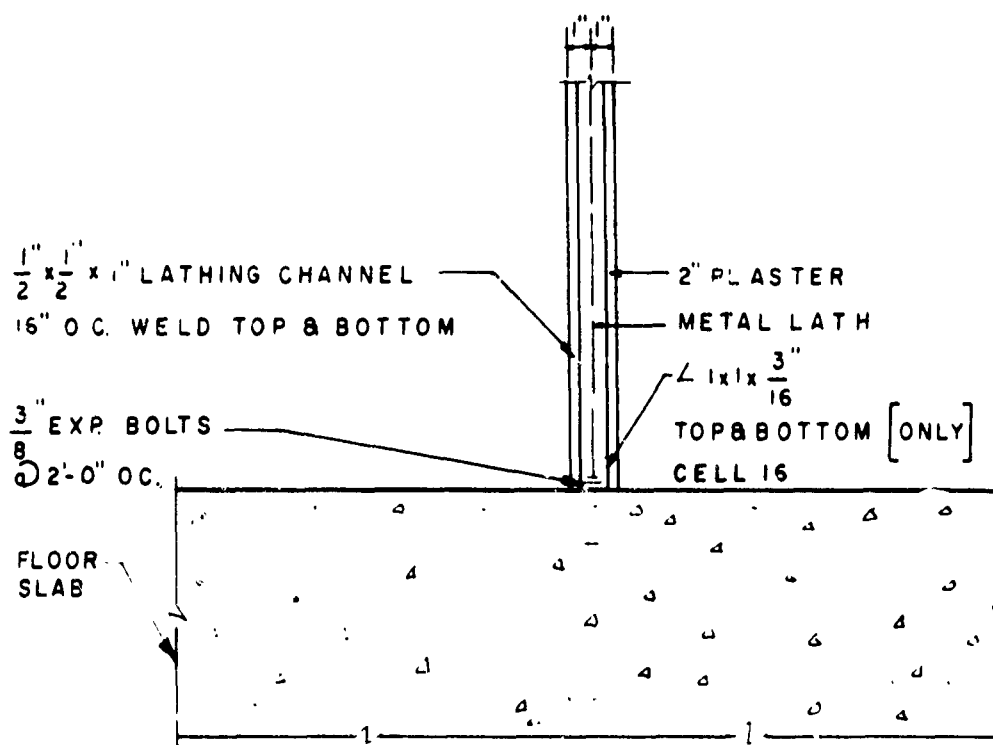


Fig. 2.234 Bottom Joint Detail (Top Similar)  
for Partitions - Cell No. 16  
Bldgs. 3.29b & 3.29d

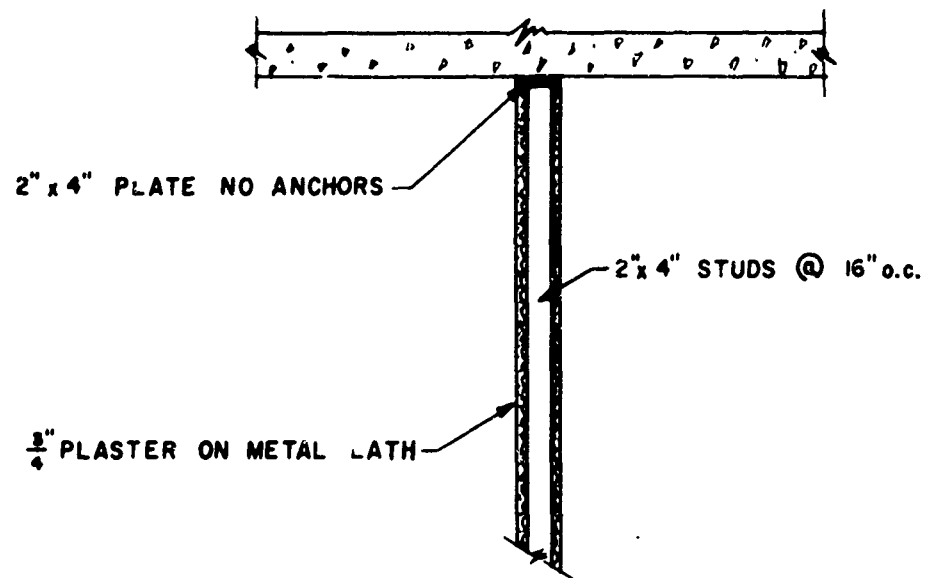


Fig. 2.235 Top Joint Detail (Bottom Similar)  
for Partitions - Cell No. 5  
Bldgs. 3.29b & 3.29d

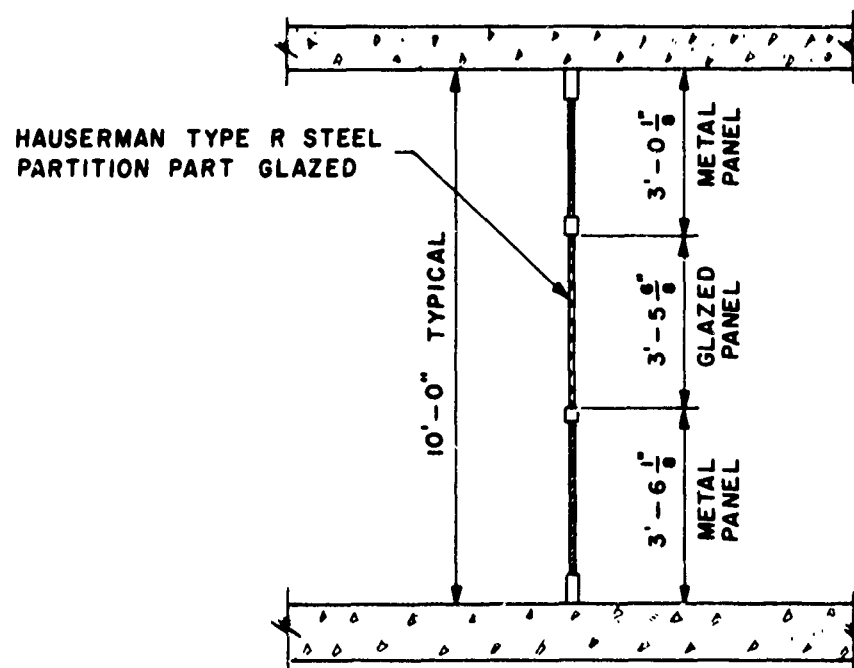


Fig. 2.236 Partitions Detail for Cell No. 6  
Bldgs. 3.29b & 3.29d

WHERE ANCHOR OCCURS IN  
BLOCK, FILL WITH MORTAR.  
PROVIDE FULL MORTAR JOINT  
IN FIRST RIB.

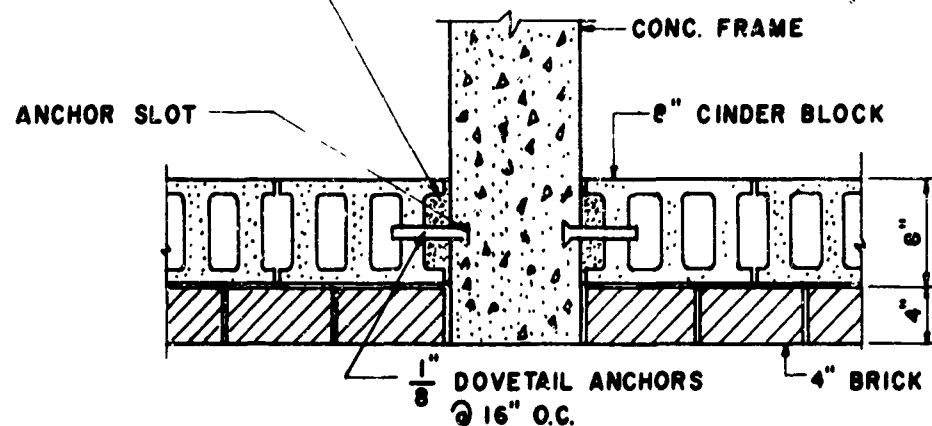


Fig. 2.237 Corner Detail Front and Rear Walls  
Bldgs. 3.29b & 3.29d

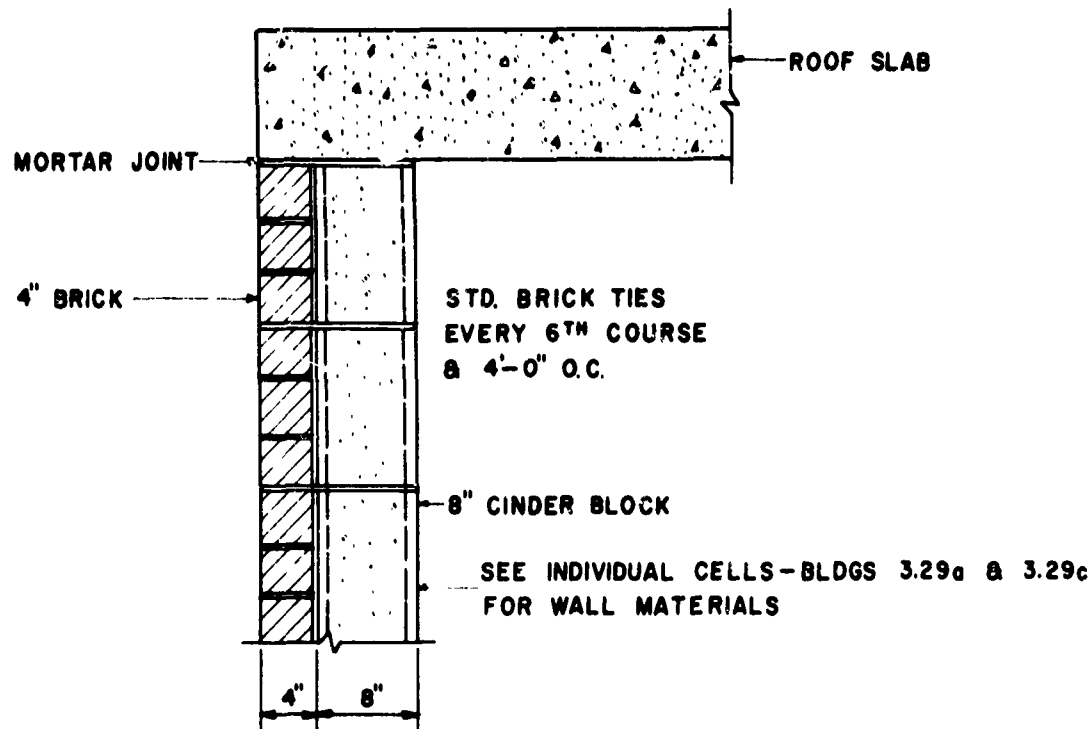


Fig. 2.238 Top Joint (Bottom Similar) for Front  
and Rear Walls - Bldgs. 3.29b & 3.29d  
& Cells No. 1-4, 6-11, & 13 - Bldgs  
3.29a & 3.29c

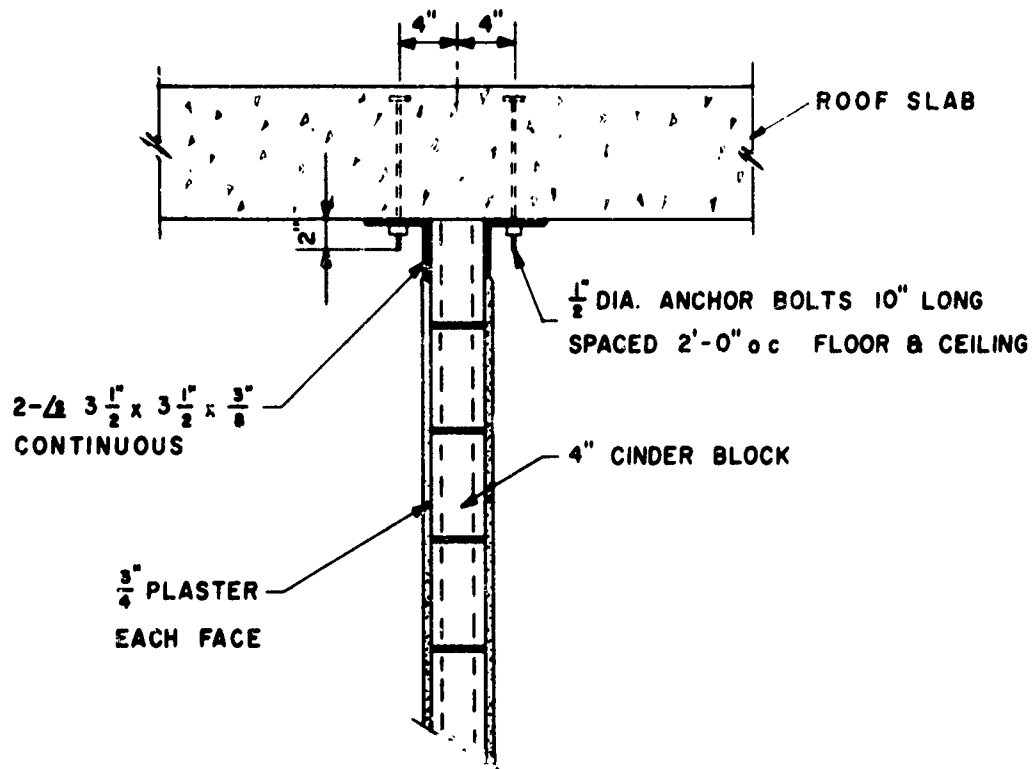


Fig. 2.239 Top Joint Detail (Bottom Similar)  
for Partitions Cell No. 7 = Bldgs  
3.29b & 3.29d

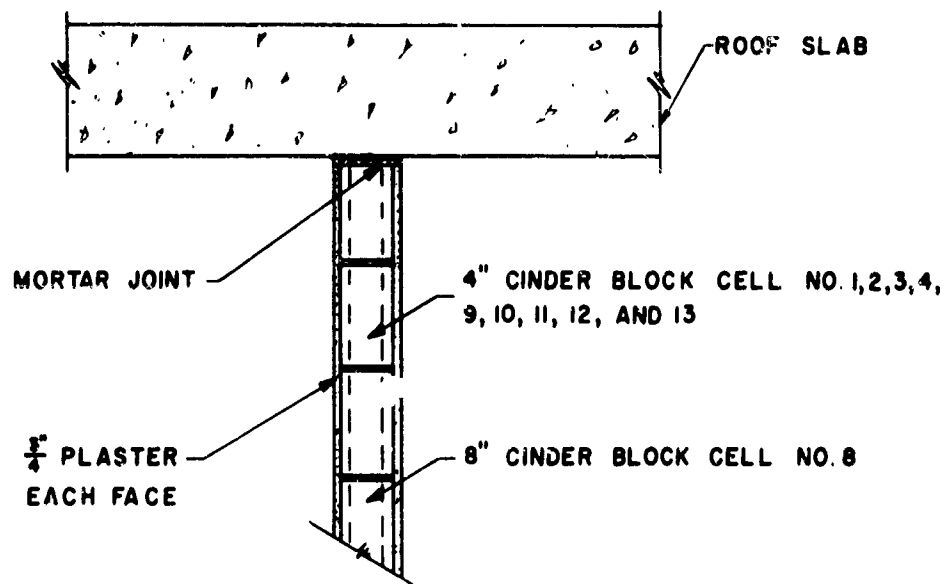


Fig. 2.240 Top Joint Detail (Bottom Similar)  
for Partitions - Cells No. 1,2,3,  
4,8,9,10,12, & 13 - Bldgs. 3.29b & 3.29d

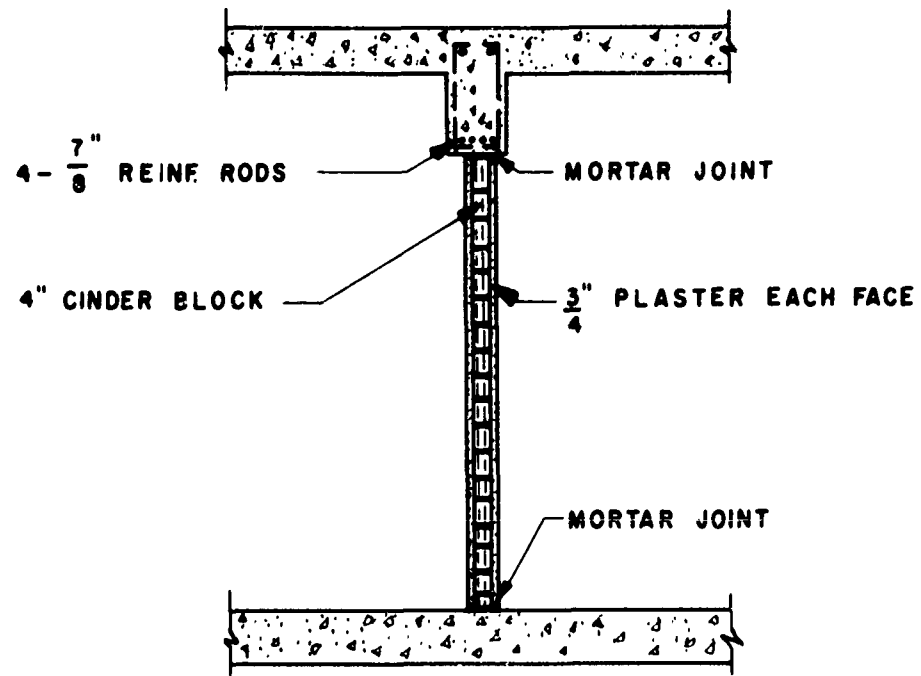


Fig. 2.241 Partition Detail for Cell No. 14  
Bldgs. 3.29b & 3.29d

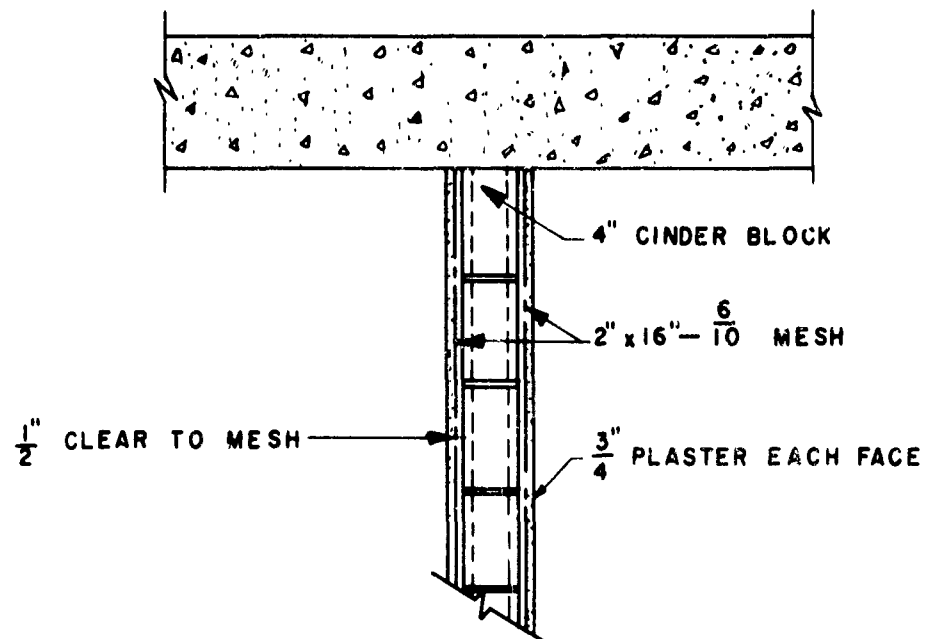


Fig. 2.242 Top Joint Detail (Bottom Similar)  
for Partitions - Cell No. 15  
Bldgs. 3.29b & 3.29d

## Chapter 3

### DISCUSSION

A comparison between computed and actual behavior of the curtain walls and interior partitions tested in Structures 3.29 a, b, c and d is presented in this section. Considering the many variables involved, these comparisons, in most instances, indicate good correlation between the theoretical and actual behaviors of the various test panels.

#### 3.1 CURTAIN WALL STRUCTURES, 3.29a AND 3.29c

The recorded blast pressures on the front and rear walls of Structures 3.29a (6,650 feet from ground zero) and 3.29c (4,450 feet from ground zero) are shown in Figures 2.3 and 2.4. It was necessary to approximate the poorly defined front wall pressure records by pressure curves with a line variation as shown in Figures 3.1 and 3.2. For comparison, computed theoretical pressures are shown on the same figures. Because of the apparent discrepancies between the recorded and theoretical values of the front wall pressures, many of the test panels have been analyzed for both theoretical and recorded pressures. No explanation is available at present to account for these discrepancies. Close agreement between recorded and theoretical values of front wall pressures was noted on a series of structures located approximately 5,000 feet from ground zero.

Materials strength field data (References 1 through 4) were as follows (compressive strength values):

Masonry mortar (average of three mixes)	3,736 psi
Brick (tested flatwise)	6,128 psi
Hollow load-bearing masonry units (gross section) 4 by 8 by 16	1,590 psi
8 by 8 by 16	1,050 psi
12 by 8 by 16	1,080 psi
Precast concrete panels	6,640 psi

Since no strength information was available for either the concrete or the reinforcing steel of the reinforced-concrete panels, the following values of ultimate static strength of concrete, and static yield point stress of reinforcing steel were assumed. In performing the analyses of the curtain walls the static strength of concrete was increased 35 percent, and the static yield strength of reinforcing steel was increased 10 percent to account for rapid rates of strain.

$$\text{Concrete: } f'_c = 3,000 \text{ psi} \quad E = 1,000 f'_c$$

$$\text{Reinforcing steel: } f_{yp} = 47,500 \text{ psi}$$

A laboratory test of the masonry mortar in-place (in the masonry unit) would have resulted in a better estimate of the effective strength of the mortar than the test data for the mortar alone. The strength of the masonry mortar unit is effected considerably by workmanship, which for best results should be above average. The effectiveness of the

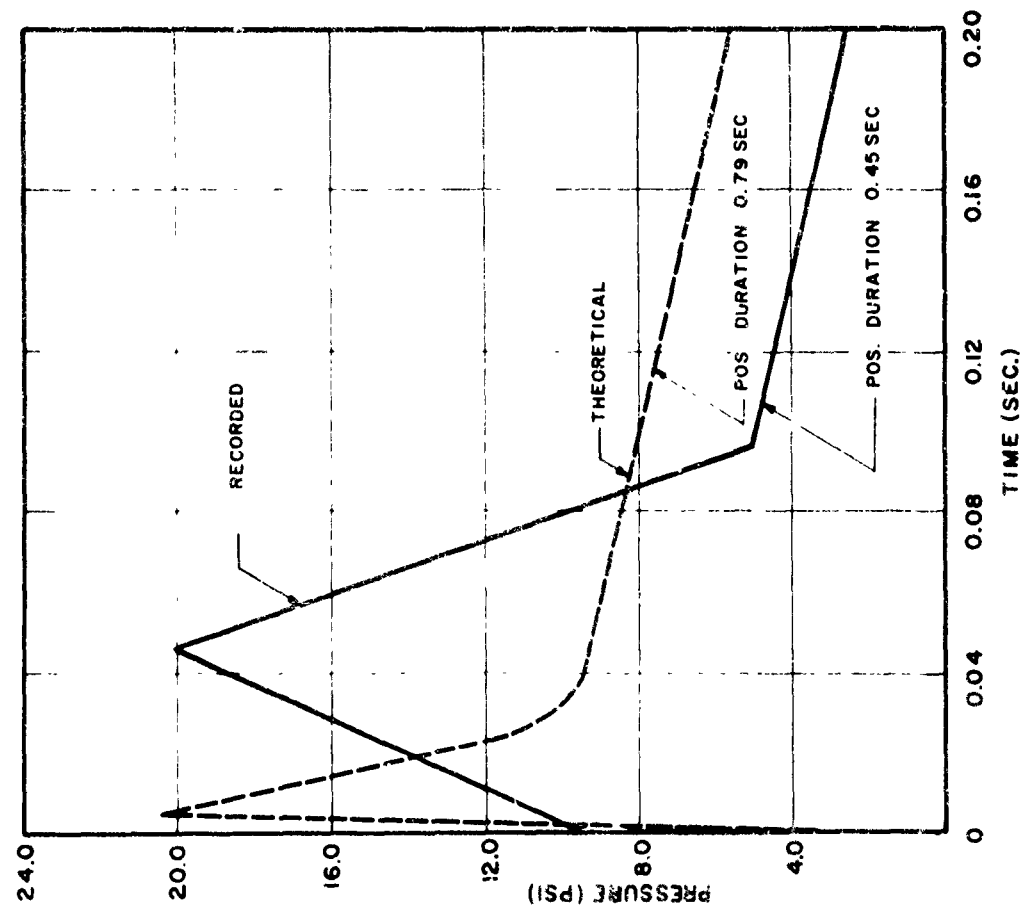


Fig. 3.1 Comparison of Recorded and Theoretical Front Wall Pressures - Bldg. 3.29c

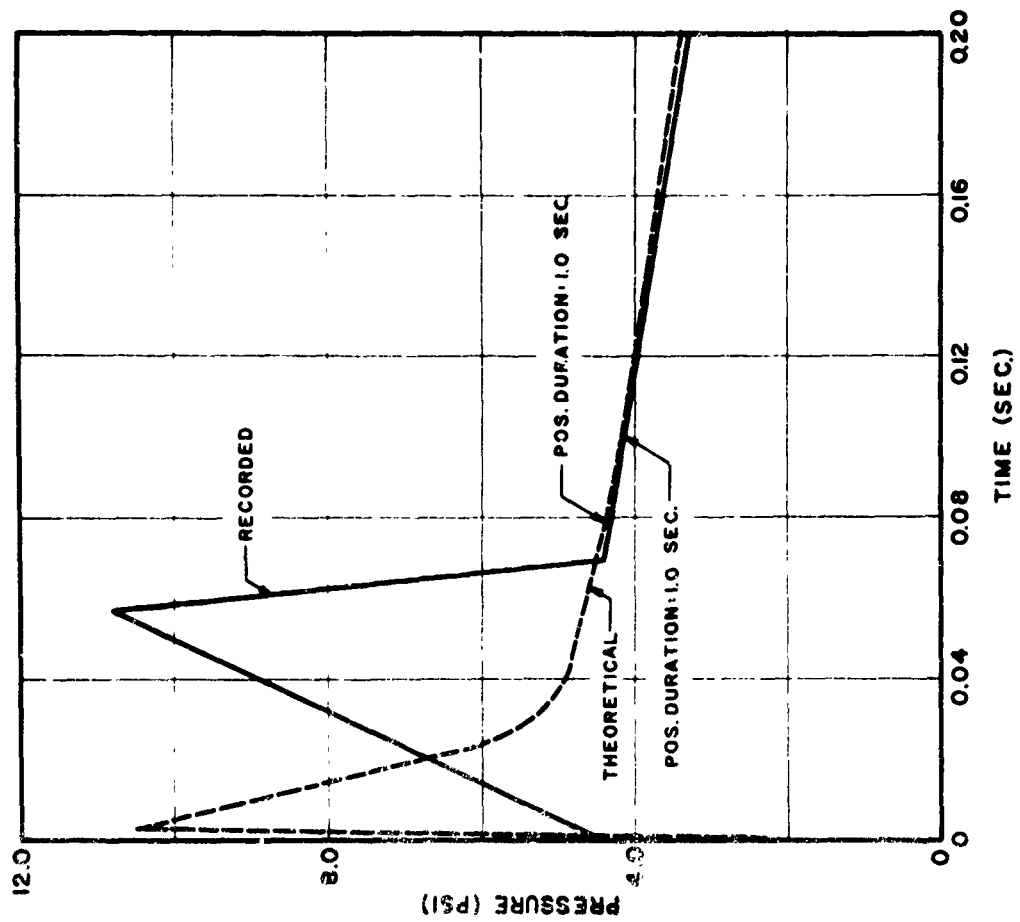


Fig. 3.2 Comparison of Recorded and Theoretical Front Wall Pressures - Bldg. 3.29a

mortar unit under blast load is reduced to some extent by local spalling of the highly compressed mortar joints. In view of these possibilities, an effective masonry mortar unit strength,  $f'_c$  of 1,000 psi, has been assumed for purposes of analyses. The value of the modulus of elasticity of the masonry unit  $E$  has been taken as  $1,000 f'_c$ . Several studies showing the effect of a variation of the assumed strength value are also described in this section.

The curtain walls, except as noted, were analyzed as one-way panels spanning between rigid supports at the roof and floor slabs. The theoretical resistance functions of the panels were computed, and the dynamic analyses were made, using a step-by-step numerical integration procedure. A summary of the recorded and calculated behavior of the curtain wall panels is given in Table 3.1, and a comparison of the recorded and calculated response values, for the panels which were instrumented, is shown in Figures 3.5 through 3.21. Pressure instrumentation was not provided on the interior face of the rear walls and therefore, for the cells in which the front walls failed, the interior pressures are not known. For this condition, theoretical interior pressures were computed and combined with the recorded rear wall (exterior) pressures for analysis (Figures 3.3, 3.4). Two theoretical rear wall interior pressures were computed using two different assumptions concerning the shape of the impulse curve. The first assumption was that the duration of peak reflected pressure is equal to the time required for the shock to travel twice the distance between the front and rear walls of the structure at the velocity of sound. The subsequent decay to stagnation pressure was assumed equal to the time required for the shock to travel three times the height of the rear wall at the velocity of sound. The second curve was computed assuming that the peak reflected pressure does not persist, but drops to stagnation pressure during an interval equal to the time required for the shock to travel twice the distance between the front and rear walls of the structure plus three times the height of the rear wall, at the velocity of sound (Reference 5). In computing the above theoretical interior pressures it was assumed that the pressure entering the structure after failure of the front wall was of the same order as the air pressure at ground level (reduced only by the breaking time at the front wall). This pressure, in turn, was assumed to be reflected at the interior face of the rear wall.

In analyzing the rear wall panels with the above pressures it was found that the assumed loadings were extremely severe and resulted in complete failure for all panels. Additional study of the rear wall panels has indicated that the front wall upon failing may distort the shock front to such an extent that the interior pressure on the rear wall would be closer to side-on pressure rather than reflected pressure. Since the use of a lower interior rear wall pressure was the only consistent way to attain a comparison of behavior for the rear wall panels, plus dynamic pressure was assumed as the loading on the interior face of the rear wall for all rear panels where the corresponding front wall panels failed.

Some indication of the shape of the blast pressures entering a windowless structure after the front wall has failed may be available from the results of Project 3.5, where pressure instrumentation was provided for this purpose. This information was not available in time to be presented in this report.

The following is a discussion of the instrumented curtain wall panels of Structures 3.2S a and c.

Panel 1F. The comparison between computed and recorded response for Panel 1F (Figures 3.5 and 3.6), a 12-inch brick wall at both ranges, was extremely good. At the far range good agreement was obtained using both recorded and theoretical pressures, while at the near range the recorded pressures indicated failure and the theoretical pressures indicated no failure. As a check on the assumed masonry mortar unit strength of



TABLE 3.1 Recorded and Calculated Values of Maximum Displacement of Curtian Walls - Bldg. 3.29 "a" and "c"

Bldg. 3.29	PANEL	MATERIAL	MAXIMUM DISPLACEMENT, x, (IN)			REMARKS
			RECORDED	CALCULATED		
				RECORDED PRESSURE	THEORETICAL PRESSURE	
a	1F	12" brick	0.47" <sup>*</sup>	0.40"	0.58"	
c	1F	12" brick	Failed <sup>*</sup>	Failed	2.50"	
a	2F	8" block	Failed	Failed	Failed	
c	2F	8" block	Failed	Failed	Failed	
a	3F	4" brick + 8" block	No Failure	Failed <sup>1</sup>	No Failure	<sup>1</sup> No failure for 10% strength increase
c	3F	4" brick + 8" block	Failed	Failed	Failed	
a	4F	4" brick + 8" block	No Failure	Failed <sup>1</sup>	No Failure	<sup>1</sup> No failure for 10% strength increase
c	4F	4" brick + 8" block	Failed	Failed	Failed	
a	5F	4" brick + 4" block	Failed	Failed	Failed	
c	5F	4" brick + 4" block	Failed	Failed	Failed	
a	6F	8" brick	No Failure	Failed <sup>1</sup>	Failed <sup>2</sup>	No failure for <sup>1</sup> 50% strength <sup>2</sup> 30% increase
c	6F	8" brick	Failed	Failed	Failed	
a	7F	12" block	Failed	Failed	No Failure <sup>2</sup>	<sup>2</sup> Failure for 5% strength decrease
c	7F	12" block	Failed	Failed	Failed	
a	8F	4" brick + 4" block	Failed	Failed	Failed	
c	8F	4" brick + 4" block	Failed	Failed	Failed	
a	9F	4" brick + 8" block	Failed	Failed	Failed	2" cavity between brick & block 2" cavity between brick & block
c	9F	4" brick + 8" block	Failed	Failed	Failed	
a	10F	4" brick + 8" block	1.49" <sup>*</sup>	Failed <sup>1</sup>	2.62"	<sup>1</sup> No failure for 10% strength increase
c	10F	4" brick + 8" block	Failed <sup>*</sup>	Failed	Failed	
a	11F	4" brick + 4" block	Failed <sup>*</sup>	Failed	Failed	
c	11F	4" brick + 4" block	Failed	Failed	Failed	
a	12F	4" brick + 8" block	Failed <sup>*</sup>	Failed	Failed	0.75" clearance at top of wall 0.75" clearance at top of wall
c	12F	4" brick + 8" block	Failed	Failed	Failed	
a	13F	4" brick + 4" tile	Failed <sup>*</sup>	Failed	Failed	
c	13F	4" brick + 4" tile	Failed	Failed	Failed	
a	14F	8" reinf. concrete	0.17" <sup>*</sup>	0.10"	0.11"	
c	14F	8" reinf. concrete	0.62" <sup>*</sup>	0.23"	0.51"	
a	15F	----				
c	15F	12" reinf. brick	0.89" <sup>*</sup>	2.85"	1.6"	
a	16F	----				Top of wall displaced in 1 ft., and center appears to have displaced in several inches.
c	16F	----				
a	17F	----				
c	17F	----				
a	18F	----				
c	18F	----				

\* Instrumented Panels

TABLE 3.1 (con't)

BLDG 3.29	PANEL	MATERIAL	MAXIMUM DISPLACEMENT, $\delta$ , (IN.)			REMARKS
			RECORDED	CALCULATED		
				RECORDED PRESSURE	THEORETICAL PRESSURE	
a	1K	12" brick	No Failure	No Failure	----	Front wall failed
c	1K	12" brick	No Failure	----	No Failure	
a	2K	8" block	No Failure	----	No Failure	Front wall failed
c	2K	8" block	Failed	----	Failed	Front wall failed
a	3K	4" brick + 8" block	No Failure	No failure	----	Front wall failed
c	3K	4" brick + 8" block	No Failure	----	No Failure	
a	4K	4" brick + 8" block	No Failure	No Failure	----	Front wall failed
c	4K	4" brick + 8" block	No Failure	----	No Failure	
a	5K	4" brick + 4" block	No Failure	----	No Failure	Front wall failed
c	5K	4" brick + 4" block	No Failure	----	Failed	Front wall failed
a	6K	8" brick	No Failure	No failure	----	Front wall failed
c	6K	8" brick	No Failure	----	No Failure	
a	7K	12" block	No Failure	----	No Failure	Front wall failed
c	7K	12" block	Failed	----	No Failure	Front wall failed
a	8K	4" brick + 4" block	No Failure	----	No Failure	Front wall failed
c	8K	4" brick + 4" block	Failed	----	Failed	Front wall failed, rear wall did not collapse.
a	9K	4" brick + 8" block	No Failure	----	No Failure	2" cavity between brick & block Front wall failed
c	9K	4" brick + 8" block	No Failure	----	No Failure	
a	10K	4" brick + 8" block	0.15"*	0.40"	----	Front wall failed
c	10K	4" brick + 8" block	No Failure	----	No Failure	
a	11K	4" brick + 4" block	+0.42"; -0.73"	----	+1.63"; -2.94"	Front wall failed, gauge cable broke
c	11K	4" brick + 4" block	Failed	----	Failed	
a	12K	4" brick + 8" block	+0.29"; -0.21"	----	+3.34"; -1.52"	Front wall failed; wire clamp out
c	12K	4" brick + 8" block	No Failure	----	No Failure	
a	13K	4" brick + 4" tile	No Failure	----	No Failure	Front wall failed
c	13K	4" brick + 4" tile	Failed	----	Failed	Front wall failed
a	14K	8" reinf. concrete	No Failure	No Failure	----	4.47" defl. not observed in field
c	14K	8" reinf. concrete	0.20"*	0.04"	----	
a	15K	8" reinf. brick	0.32"*	0.23"	----	
c	15K	8" reinf. brick	4.47"*	0.41"	----	
a	16K	22 ga. corrug. metal	No Failure	No Failure	----	Girt supports also failed
c	16K	22 ga. corrug. metal	Failed	Failed	----	Girt supports also failed
a	17K	corrugated transite	Failed	Failed	----	Girt supports did not fail
c	17K	corrugated transite	Failed	Failed	----	Girt supports did not fail
a	18K	precast reinf. conc.	No Failure	No Failure	----	
c	18K	precast reinf. conc.	Failed	Failed	----	

\* Instrumented Panels

\*\* 0.75" clearance at top of wall

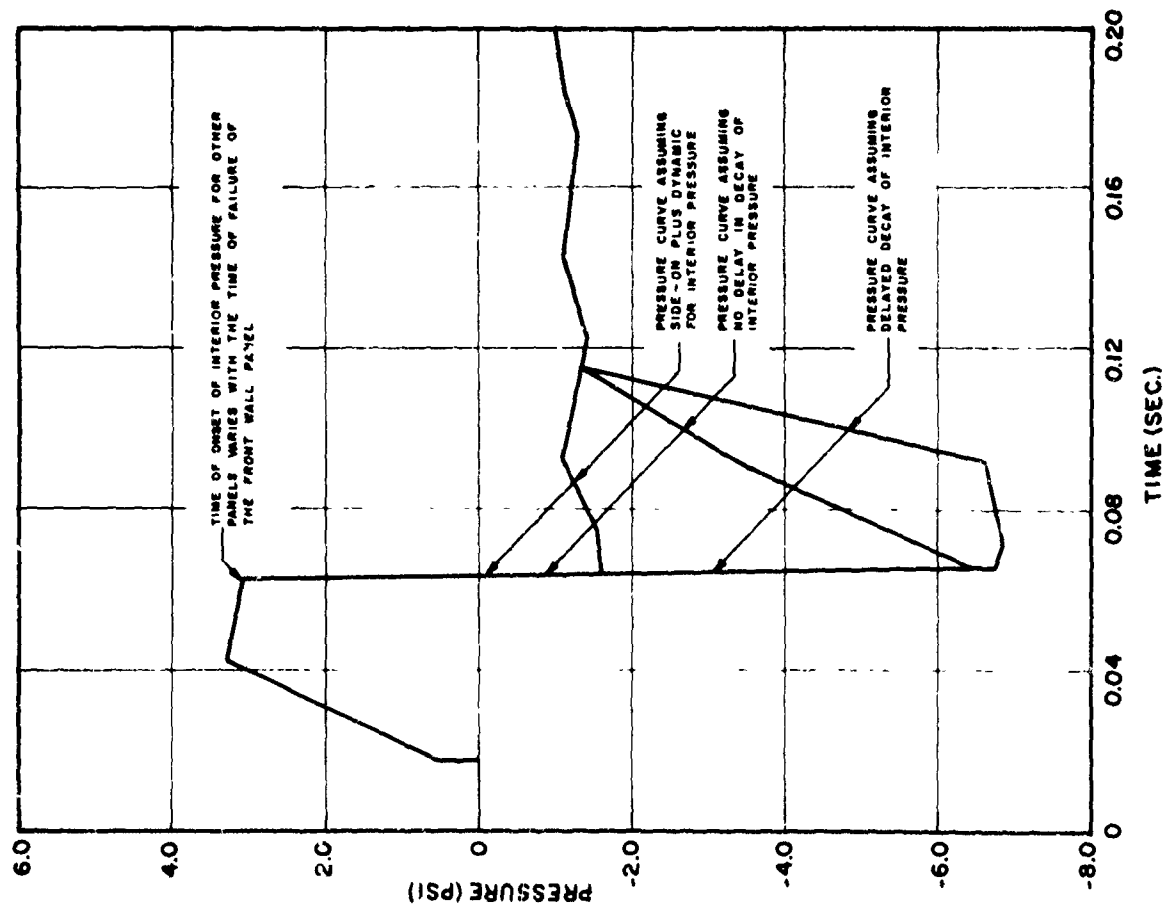


Fig. 3.3 Assumed Rear Panel Net Pressure (Front Panel Failed) - Bldg. 3.29a - Panel 11h

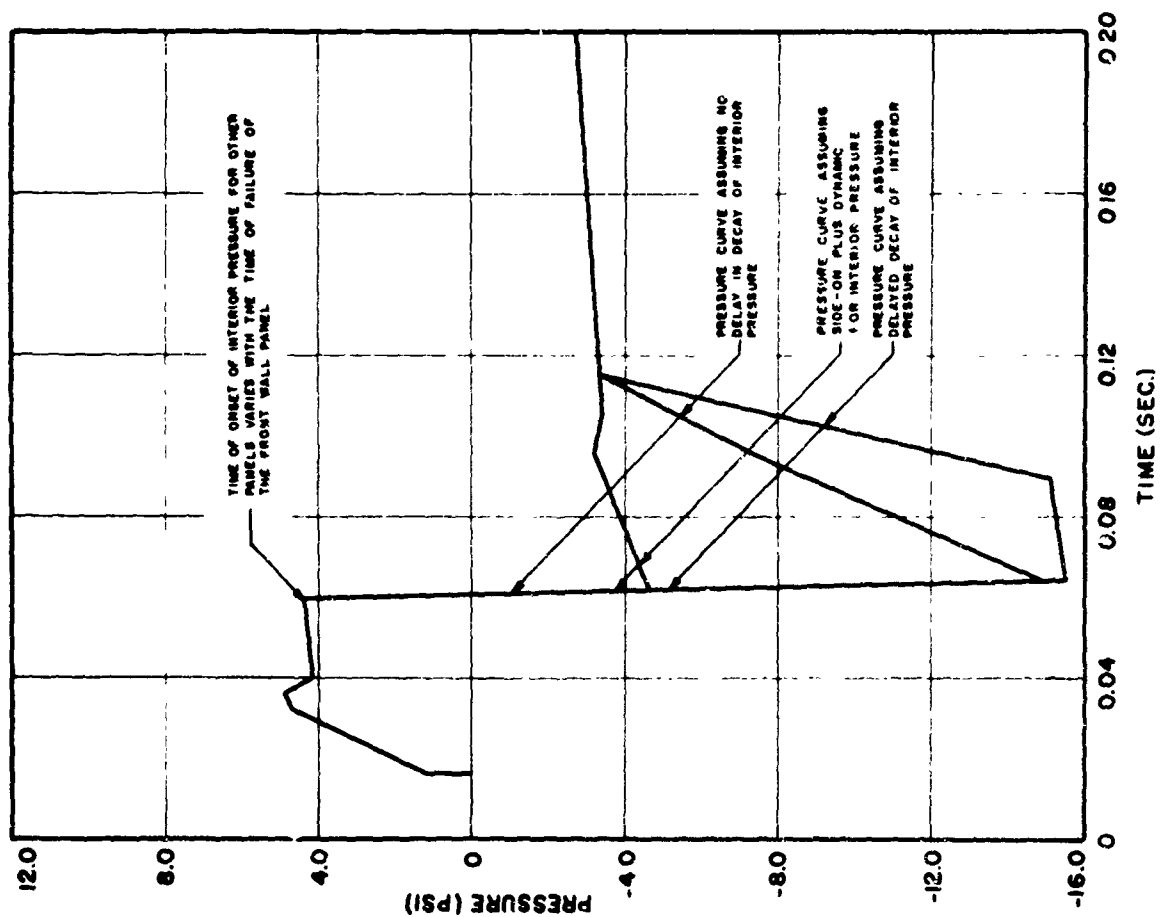


Fig. 3.4 Assumed Rear Panel Net Pressure (Front Panel Failed) - Bldg. 3.29c - Panel 10f

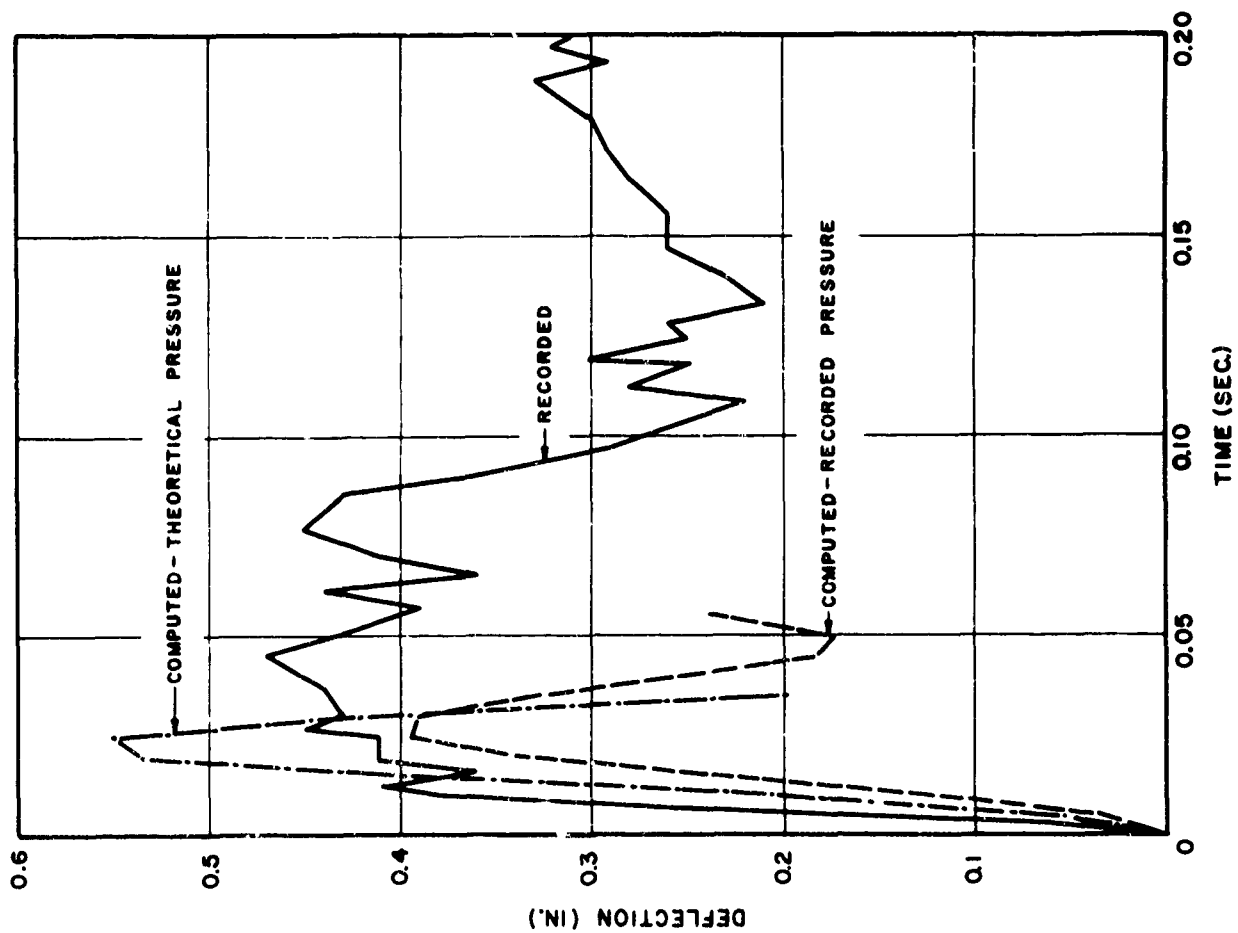


Fig. 3.5 Comparison of Recorded and Computed Deflections - Bldg. 3.4a - Panel 1F

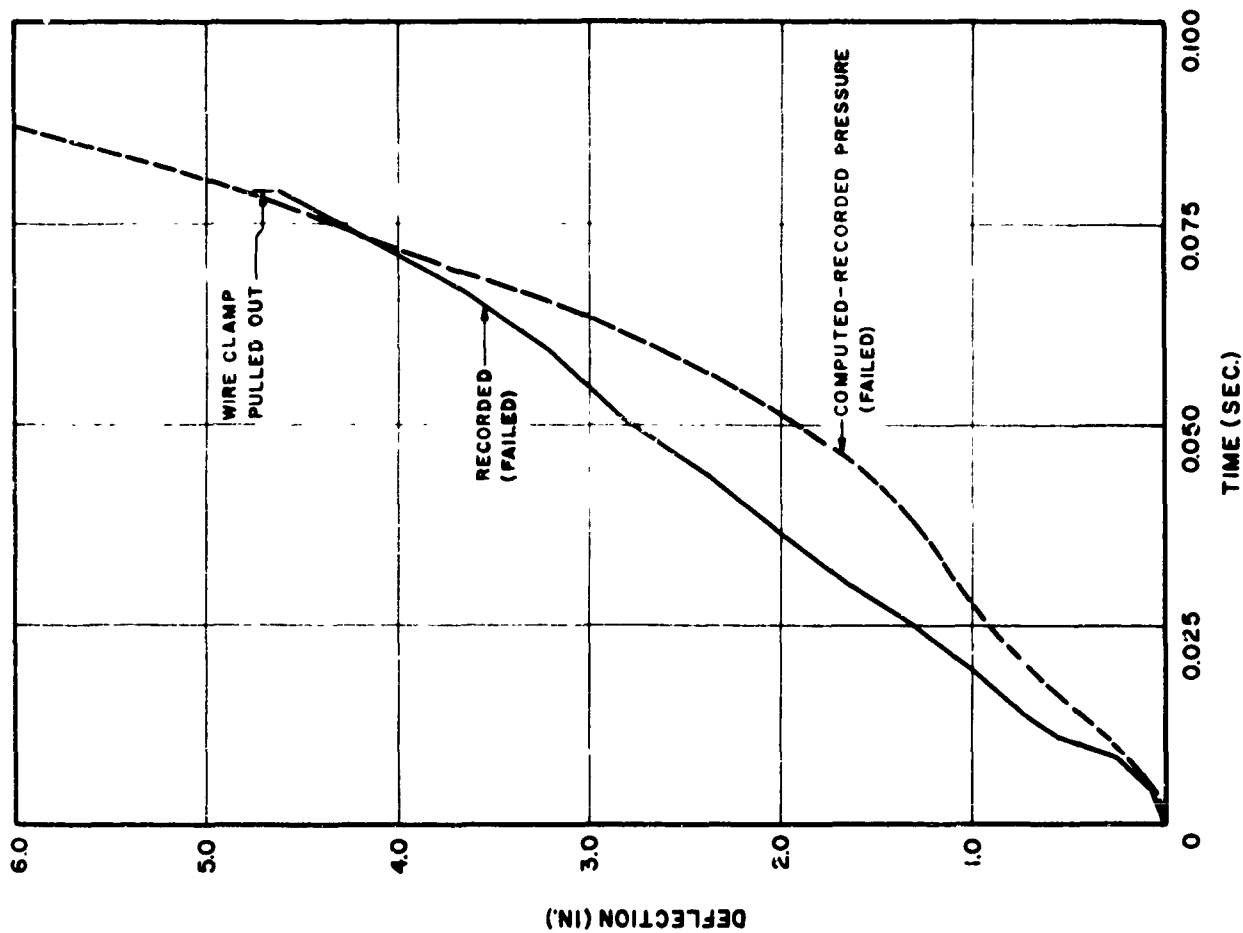


Fig. 3.6 Comparison of Recorded and Computed Deflections - Bldg. 3.79c - Panel 1F

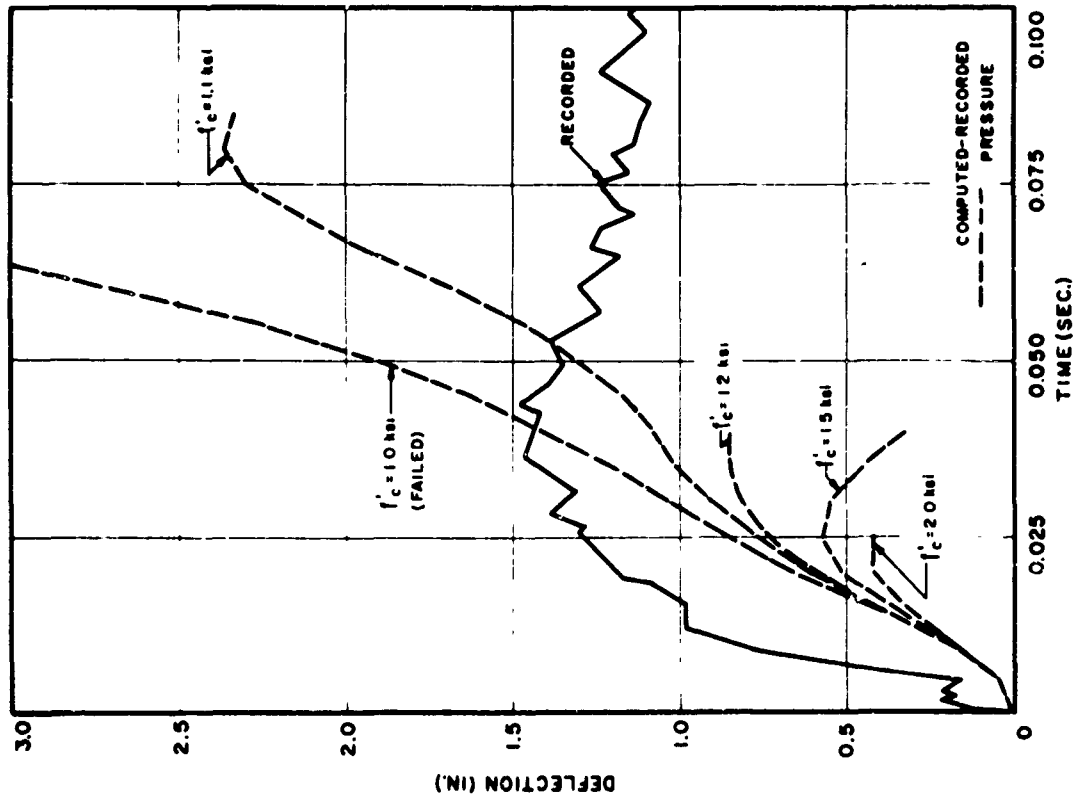


Fig. 3.3 Effect of Variation of Mortar Strength on Panel Deflection - Bldg. 3.29a - Panel 10F

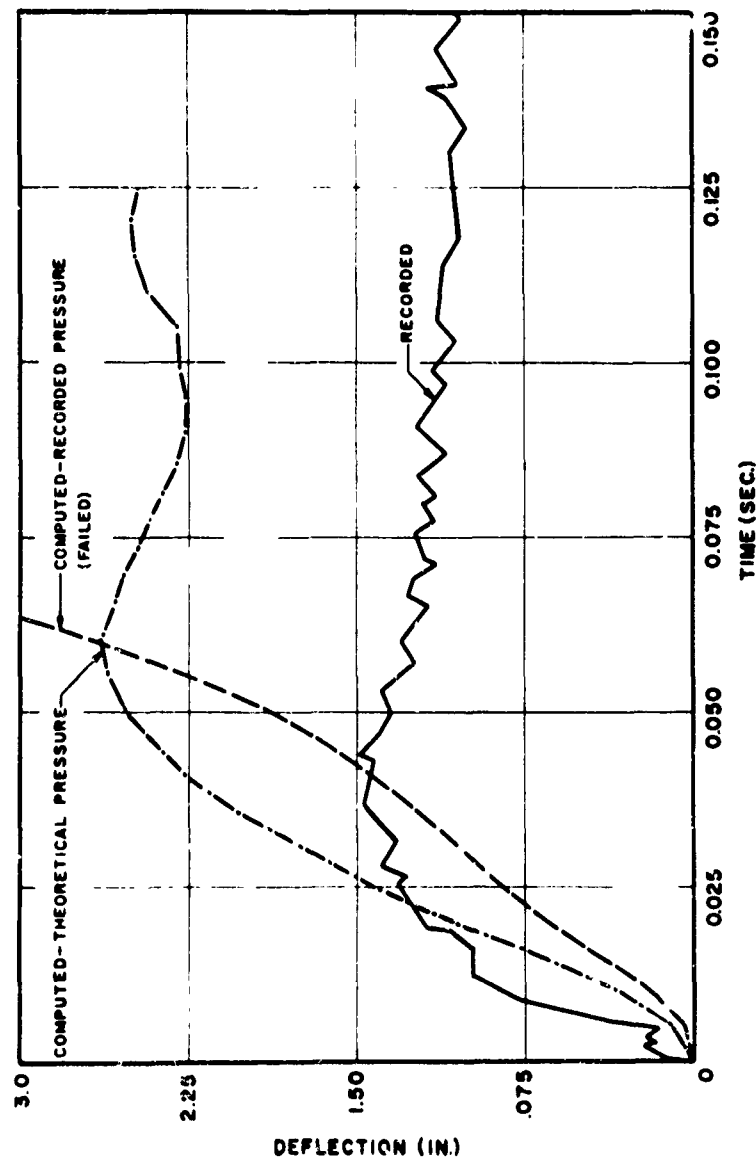


Fig. 3.7 Comparison of Recorded and Computed Deflections Bldg. 3.29a - Panel 10F

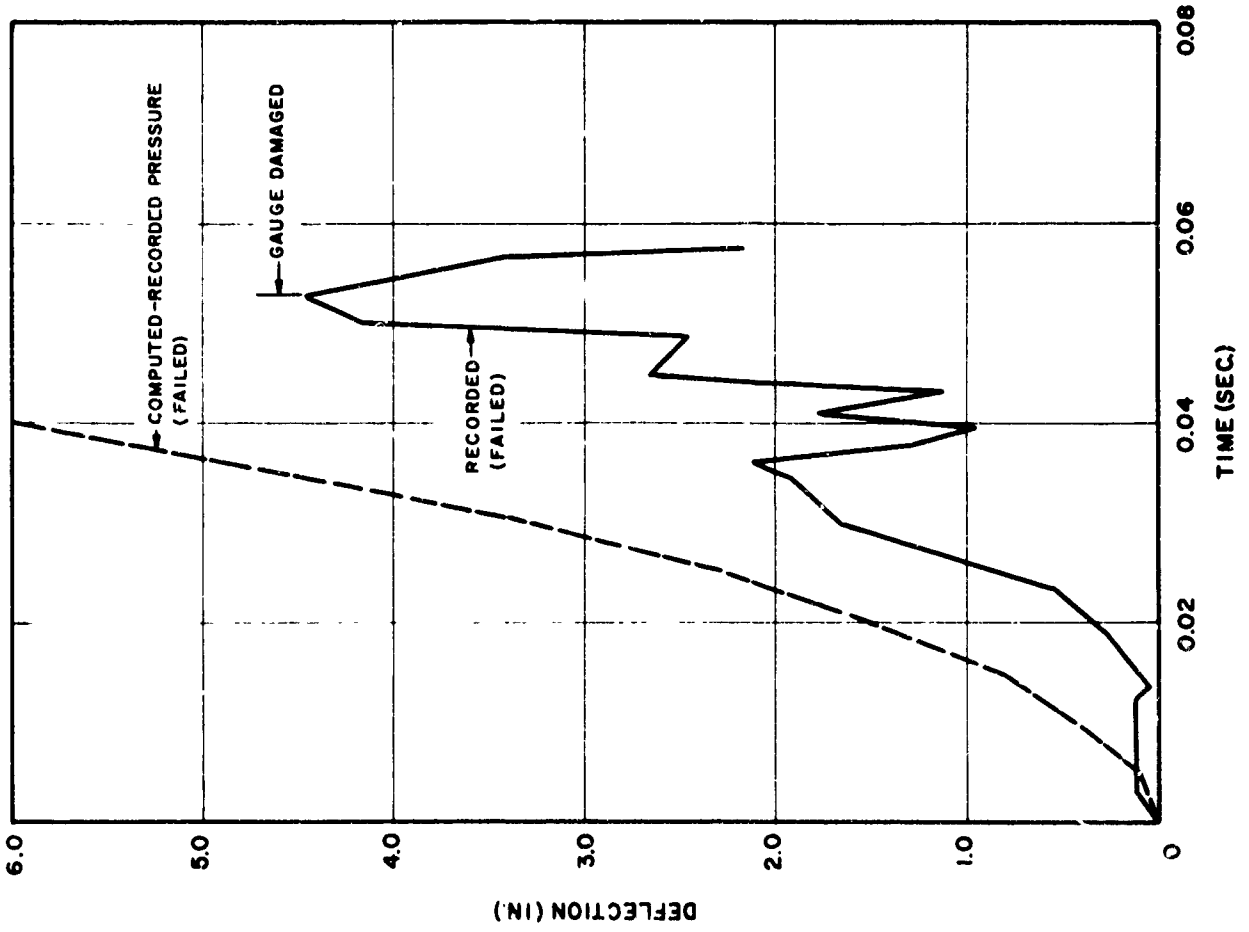


Fig. 3.9 Comparison of Recorded and Computed Deflections - Bldg. 3.29c - Panel 10F

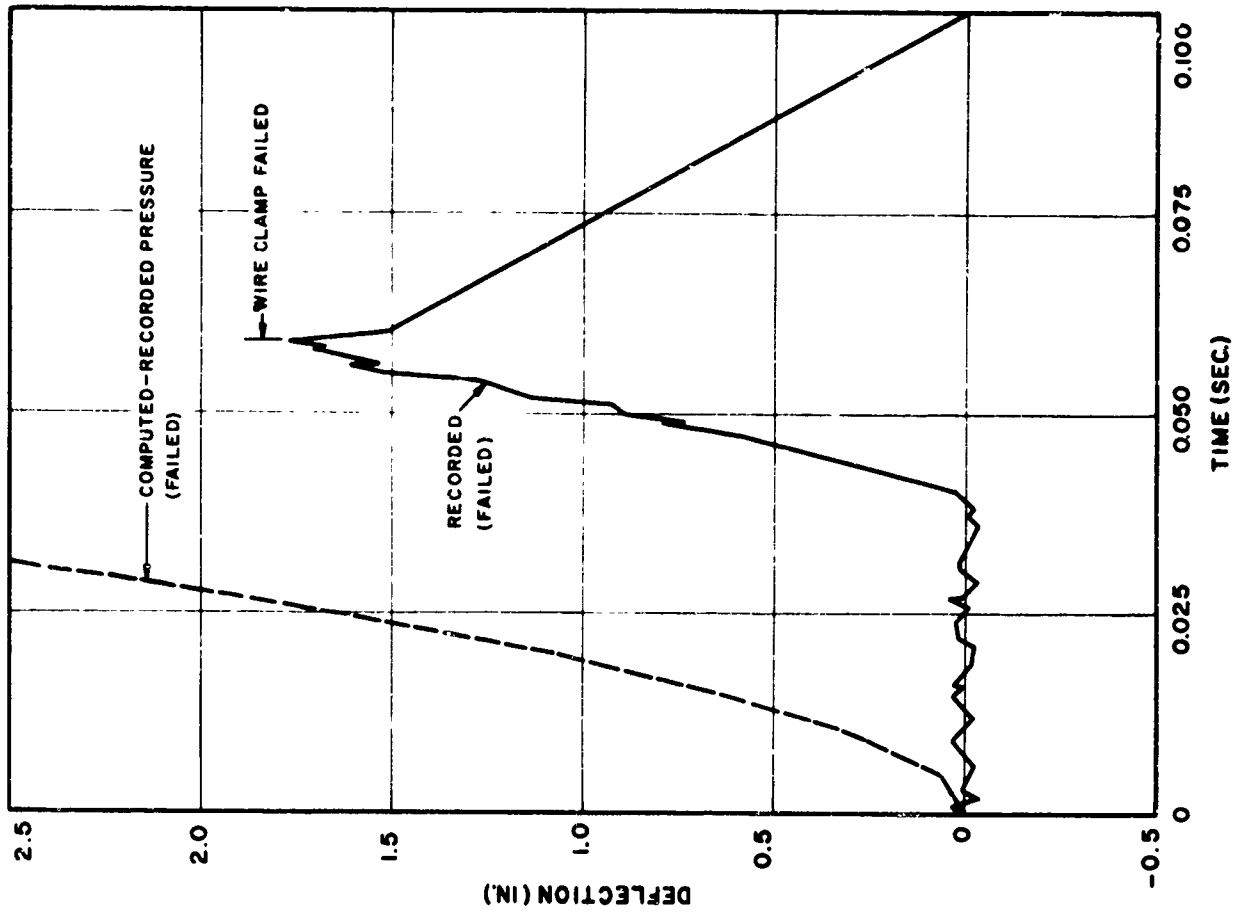


Fig. 3.10 Comparison of Recorded and Computed Deflections - Bldg. 3.29a - Panel 11F

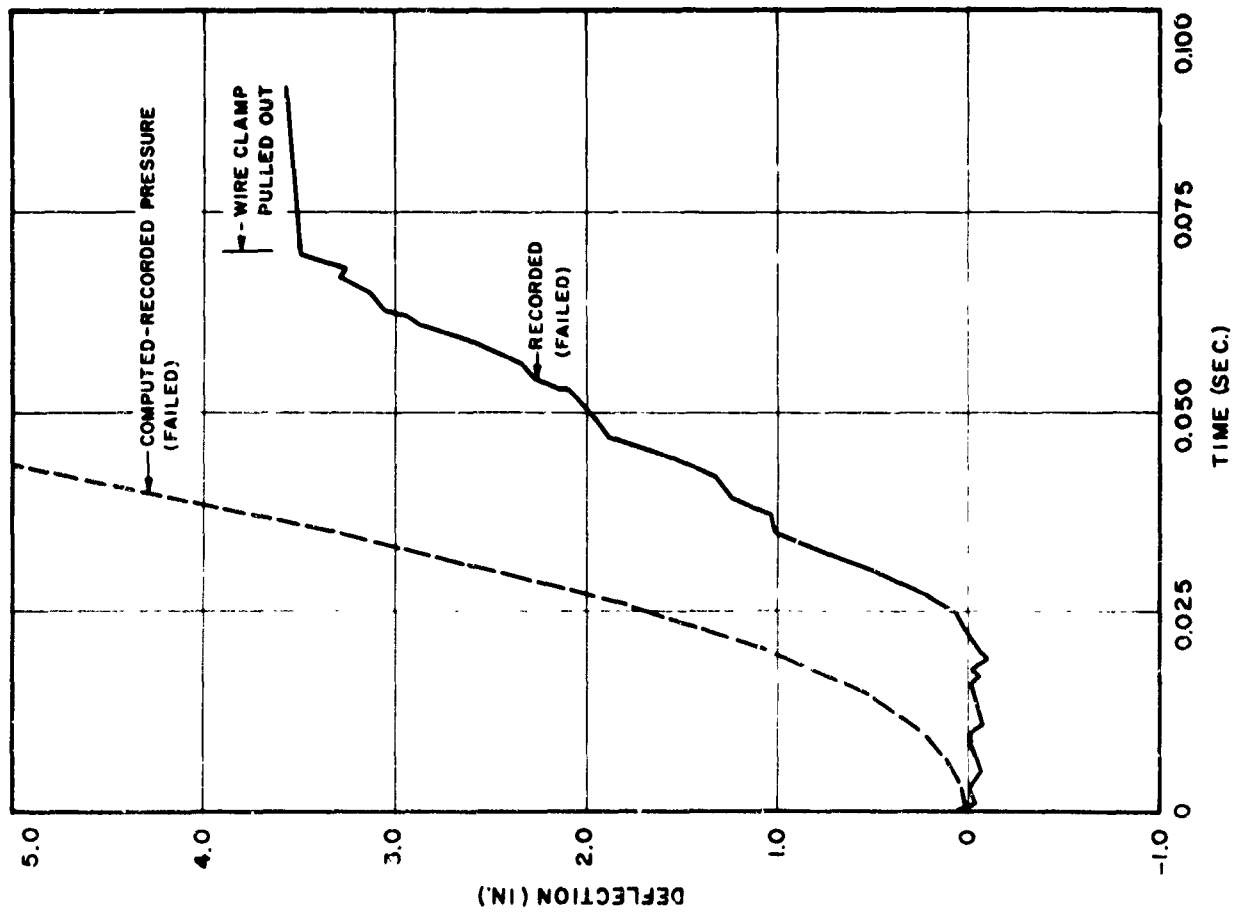


Fig. 3.11 Comparison of Recorded and Computed Deflections - Bldg. 3.29a - Panel 12F

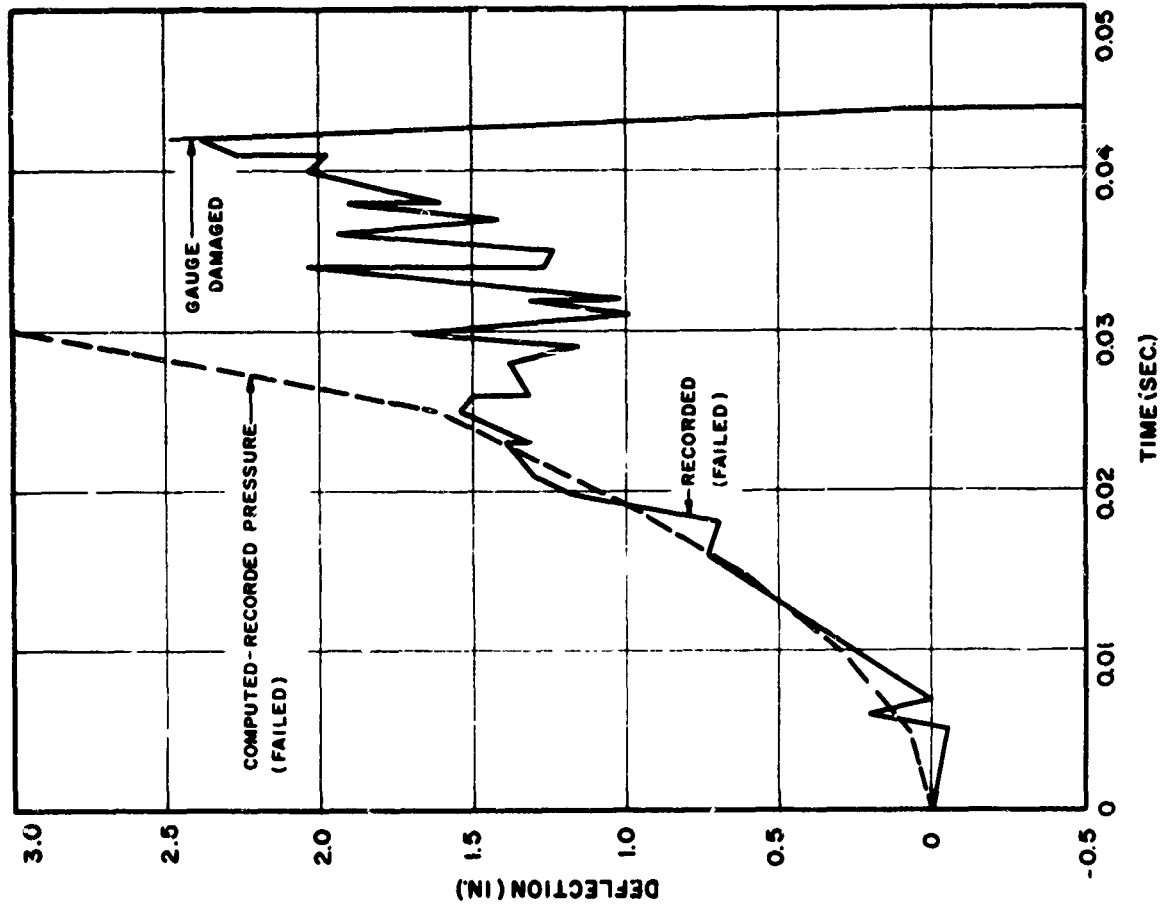


Fig. 3.12 Comparison of Recorded and Computed Deflections - Bldg. 3.29a - Panel 13F

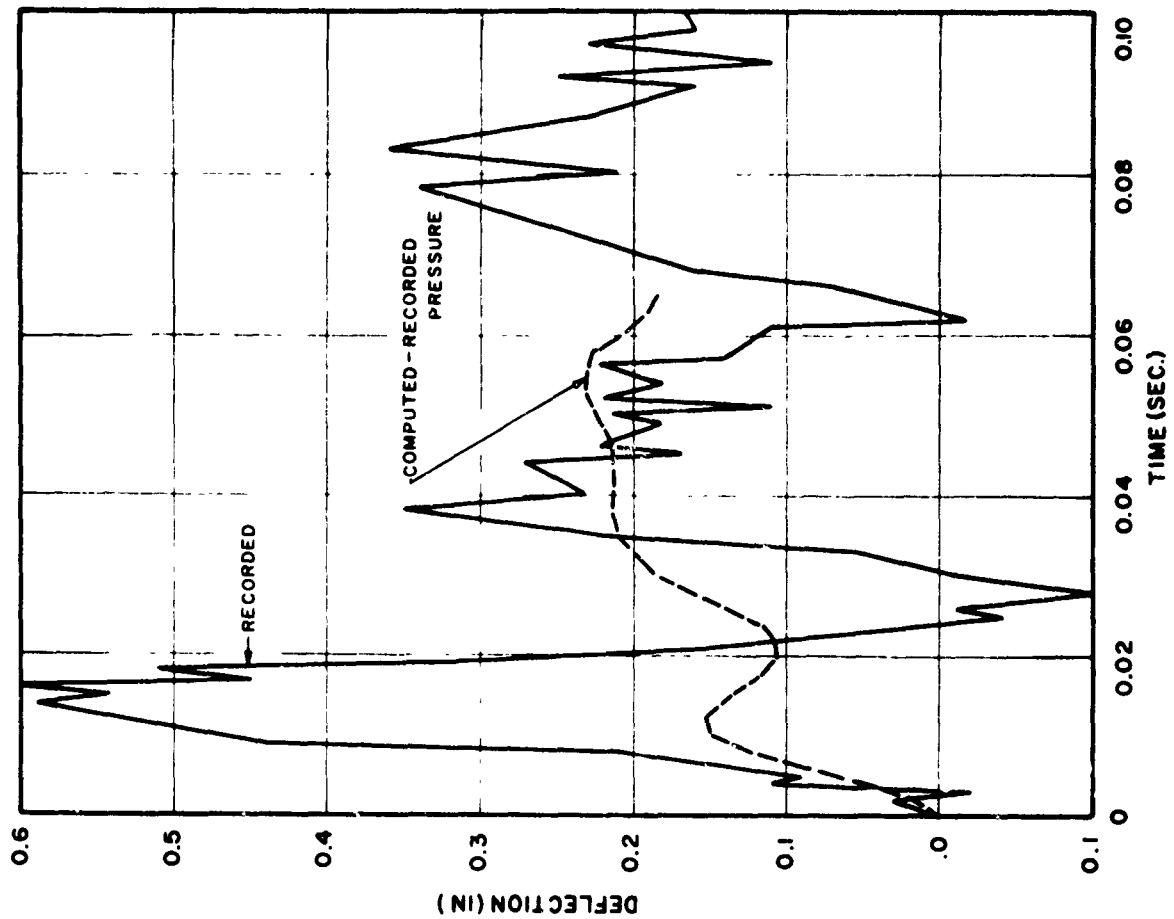


Fig. 3.14 Comparison of Recorded and Computed Deflection - Bldg. 3.29c - Panel 14F

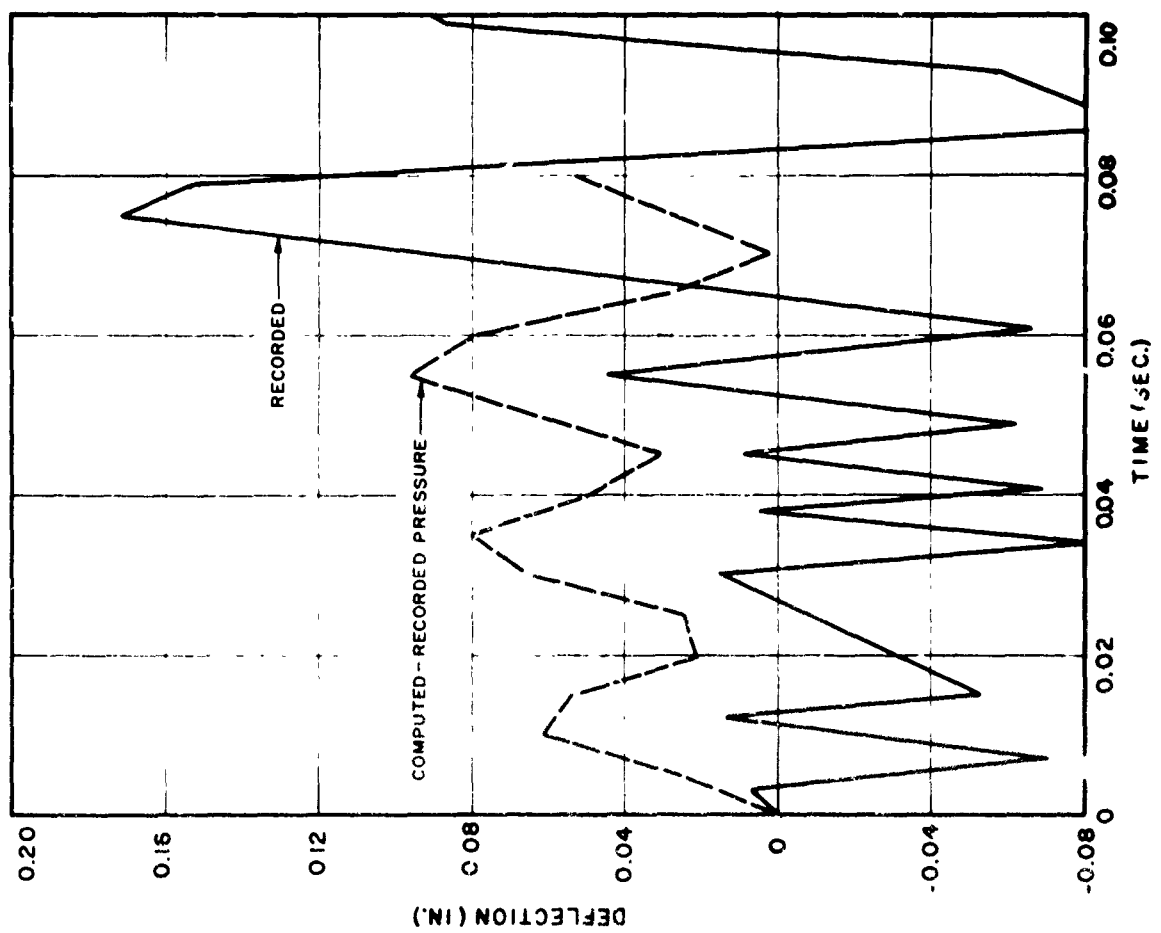


Fig. 3.13 Comparison of Recorded and Computed Deflections - Bldg. 3.29a - Panel 14F



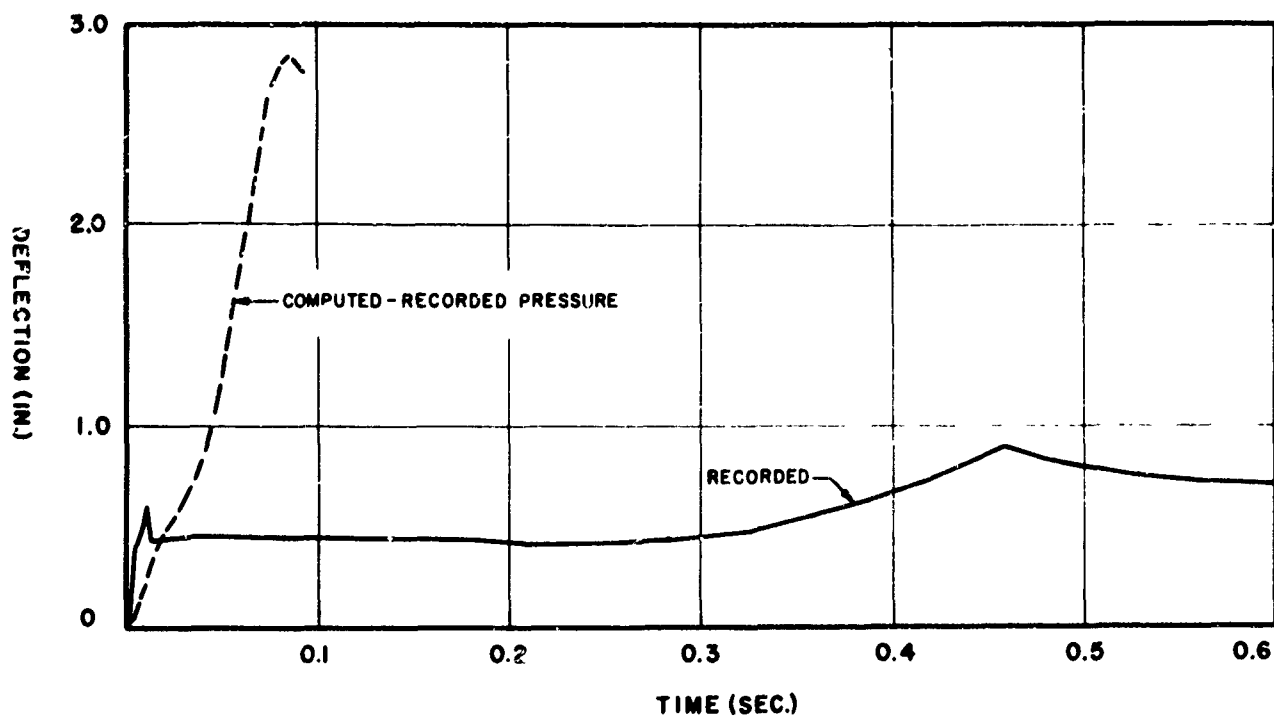


Fig. 3.15 Comparison of Recorded and Computed Deflections - Bldg. 3.29c - Panel 15F

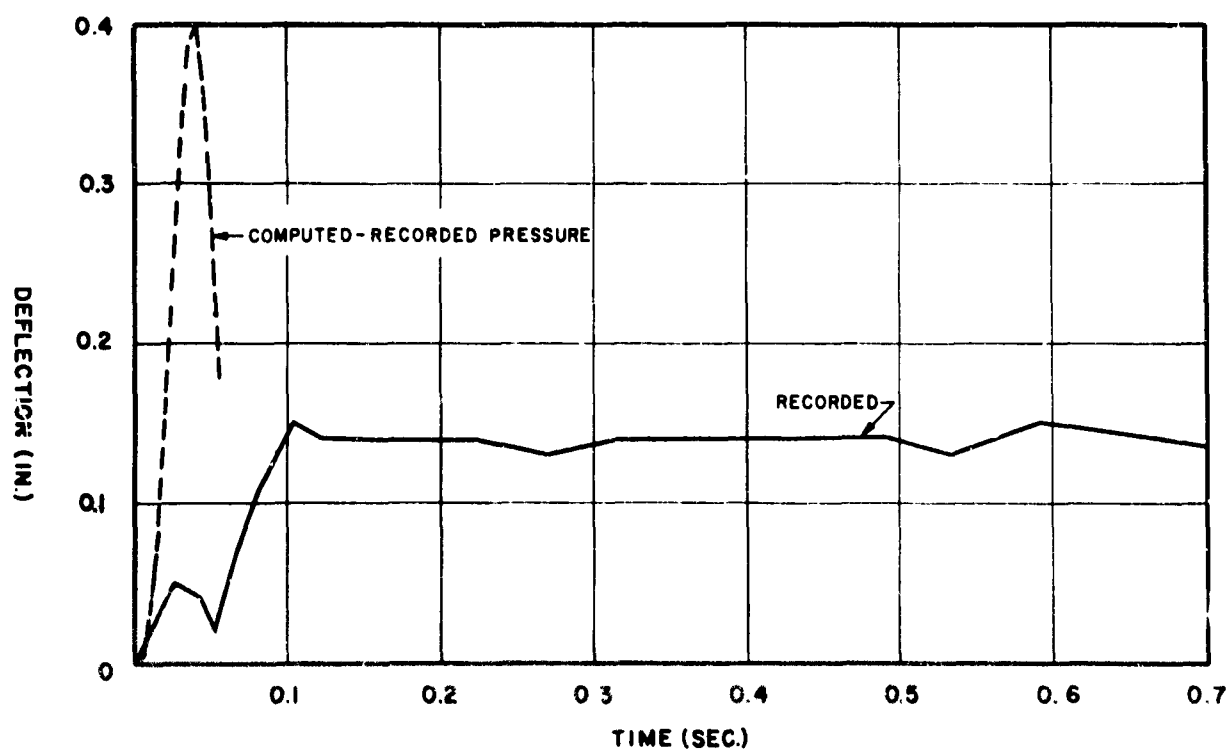


Fig. 3.16 Comparison of Recorded and Computed Deflections - Bldg. 3.29a - Panel 10H

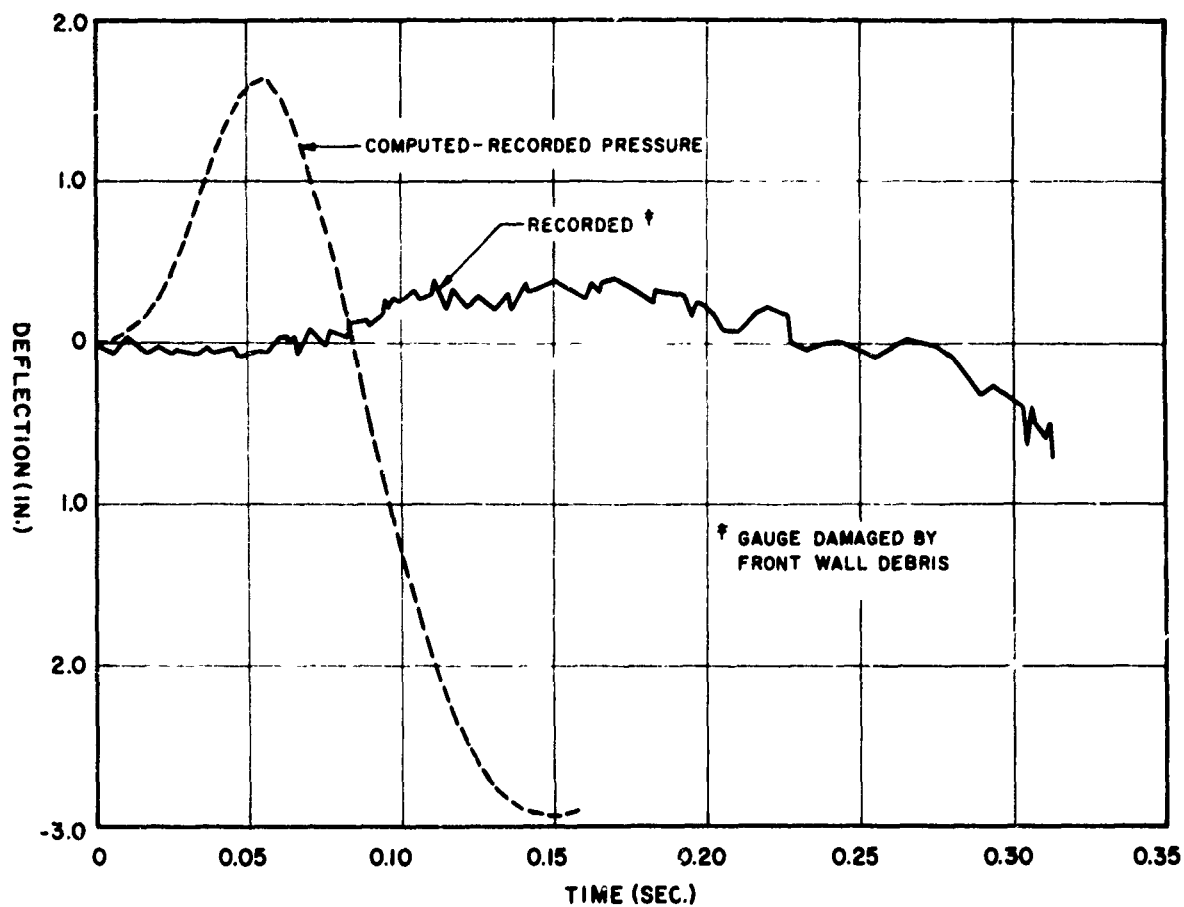


Fig. 3.17 Comparison of Recorded and Computed Deflections - Bldg. 3.29a - Panel 11R

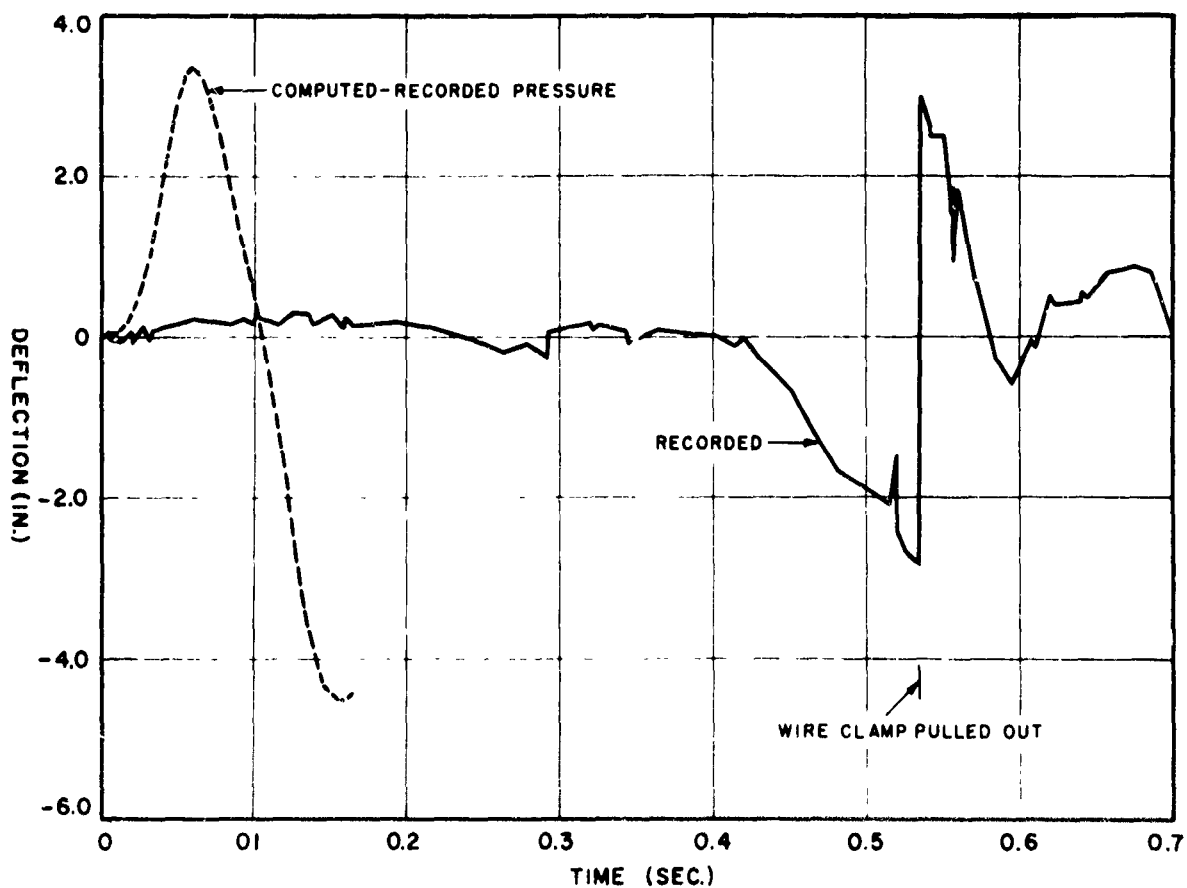


Fig. 3.18 Comparison of Recorded and Computed Deflections- Bldg. 3.29a - Panel 12R

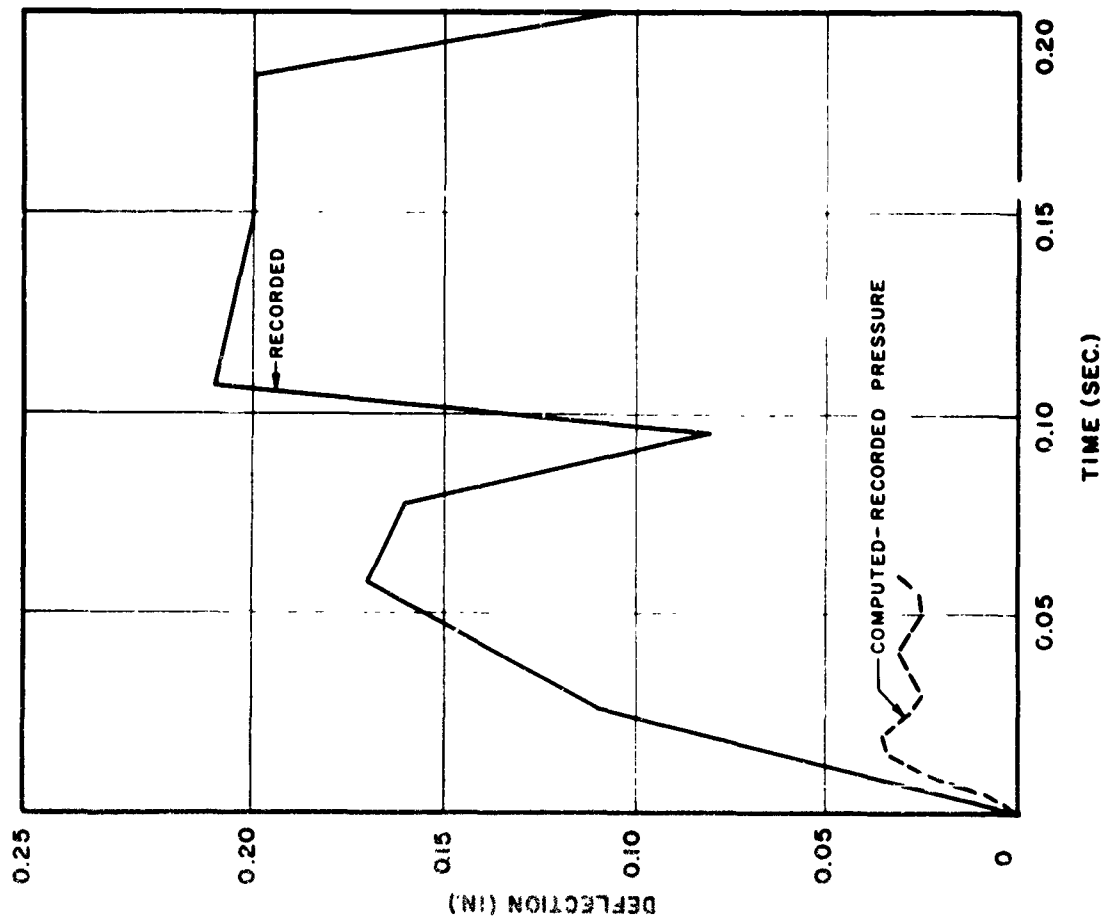


Fig. 3.19 Comparison of Recorded and Computed Deflections - Bldg. 3.29c - Panel 14R

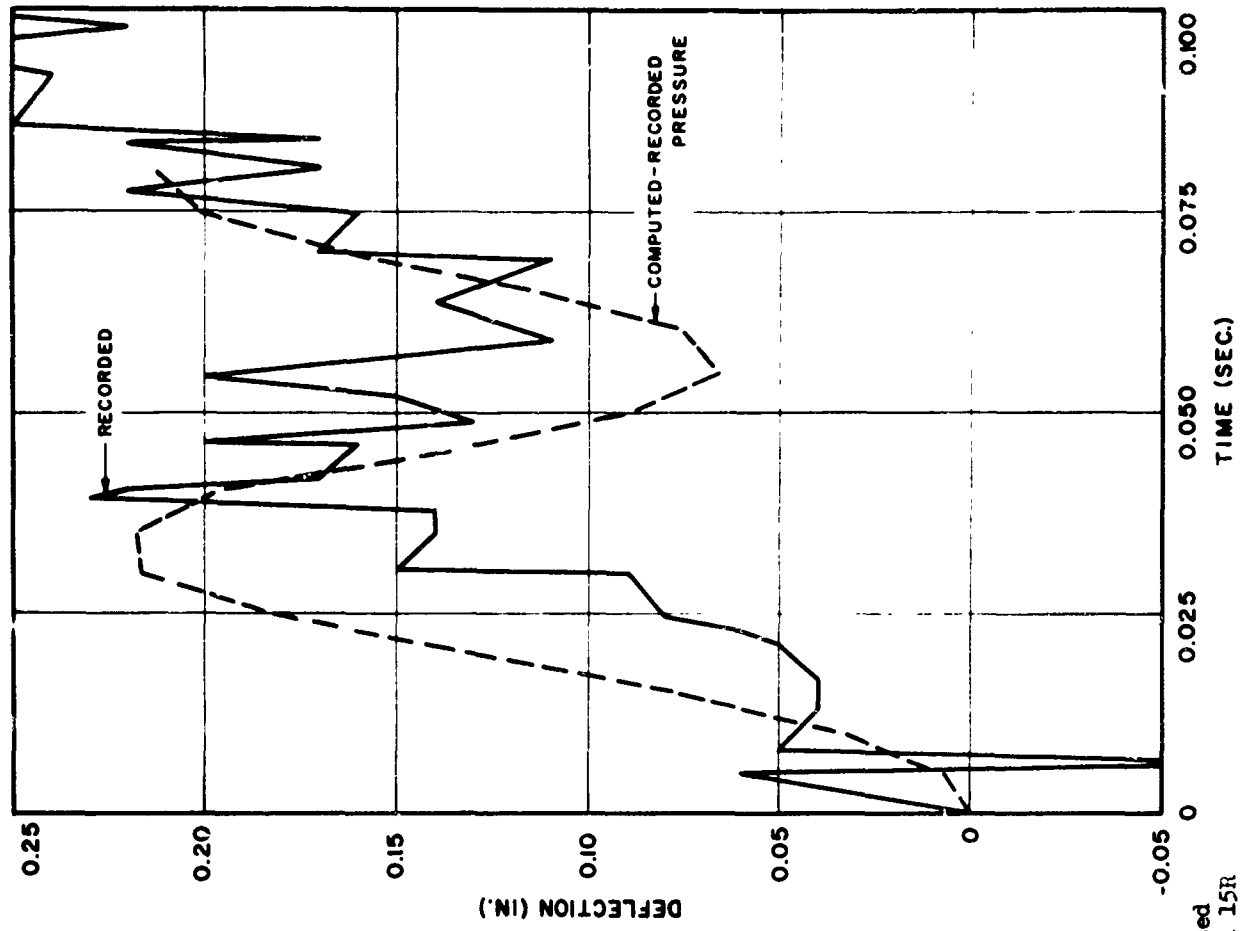


Fig. 3.20 Comparison of Recorded and Computed Deflections - Bldg. 3.29a - Panel 15R

$f'_c = 1,000$  psi, the near range panel, which failed, was analyzed with the recorded pressures for an assumed strength of  $f'_c = 1,100$  psi. The resulting analysis showed that failure would not occur, indicating that values of  $f'_c$  greater than 1,000 psi would not be consistent with the theoretical resistance function.

Panel 10 F. The computed response (using recorded pressures) for Panel 10F, a 4-inch-brick and 8-inch-block wall, at the far range (Figure 3.7) indicated that failure, which did not occur, would occur. A study was made to show the effect of possible variations in the strength (or the modulus of elasticity) of the masonry unit. The results of this study, as shown in Figure 3.8, demonstrate the sensitivity of the response function to small changes in strength. As shown, the computed response would compare extremely well with the recorded data if the assumed strength of the unit (1,000 psi) were to be increased by approximately 10 percent. The comparison between computed and recorded response for the corresponding panel at the near range (Figure 3.9) was satisfactory to the extent that failure was indicated by the analysis. The recorded response showed an initial time lag considerably larger than the response time of the recording instrument, otherwise the calculated response is shown to build up at a rate comparable to that of the recorded values.

Panel 11 F. The comparison between computed and recorded response for Panel 11F, a 4-inch-brick and 4-inch-block wall (Figure 3.10) at the far range, was satisfactory to the extent that failure was indicated by the analysis. Except for an initial time lag demonstrated by the recorded response, the rates of build-up of recorded and computed response compare extremely well. The corresponding panel at the near range also failed.

Panel 12 F. The comparison between computed and recorded response for Panel 12F, a 4-inch-brick and 8-inch-block wall with a clearance of 0.75 inch between the top of the panel and the bottom of the roof slab (Figure 3.11) at the far range, was satisfactory to the extent that failure was indicated by the analysis. Except for an initial time lag demonstrated by the recorded response, the rates of build-up of recorded and computed response compare extremely well. The corresponding panel at the near range also failed.

Panel 13 F. The comparison between computed and recorded response for Panel 13F, a 4-inch-brick and 4-inch-tile wall (Figure 3.12) at the far range, was satisfactory to the extent that failure was indicated by the analysis. Very good agreement was obtained between the recorded and computed rates of build-up of the response function. The corresponding panel at the near range also failed.

Panel 14 F. The computed response values for Panel 14F, an 8-inch reinforced-concrete panel, restrained top and bottom (Figures 3.13 and 3.14) at both ranges, were lower than the recorded values. Closer agreement would be possible if the steel reinforcement, for which field test data is not available, were to exhibit a lower yield point than assumed for analysis, or if the panel reinforcing were not properly tied in at the roof or floor slab. Both panels showed better agreement when analyzed with the theoretical pressures.

Panel 15 F. The resistance function for Panel 15F, a 12-inch reinforced-brick panel at the near range (Figure 3.15), is not as intended because of the field omission of negative-moment steel at the roof level. The panel deflected inward 1 foot along the top edge, and some extent of horizontal spanning was indicated by the presence of vertical cracks at the middle top third of the panel. Depending upon the tightness of the mortar joint at the roof level, the amount of cracking in the panel, and the magnitude of the vertical load, it is possible that the initial behavior of the panel was between that of a cantilever and a fixed-pinned member. The panel evidently did not develop a sufficient horizontal reaction at the roof level, and the effect of horizontal spanning may have prevented

failure. As a fixed-pinned member, the computed value of maximum deflection was 2.85 inches. This deflection is greater than the peak recorded value (0.89 inch). Considering the 1-foot displacement of the panel at the roof level, however, it appears that the recorded displacement should have been larger; this conclusion is indicated further by the postshot photography.

Panel 10R. The maximum value of the computed response for Panel 10R, a 4-inch-brick and 8-inch-block wall at the far range (Figure 3.16), was considerably larger than the recorded value. As previously noted, a small increase in the material strength would result in much closer comparison.

The corresponding panel at the near range, which was subjected to both interior and exterior pressures, survived as indicated by analysis.

Panel 11R. Panel 11R is a 4-inch-brick and 4-inch-block wall which survived at the far range. The corresponding front wall panel, 11F, failed at this range. The comparison between computed and recorded values of deflection is shown in Figure 3.17. The computed values are greater than the recorded values, but much better agreement could not be hoped for where so many variables are involved. The recorded values are questionable because of damage to the gage cable caused by debris. Further study is required with regard to the interior pressure.

The corresponding panel at the near range failed as indicated by analysis.

Panel 12R. The loading on Panel 12R, a 4-inch-brick and 8-inch-block wall with a clearance of 0.75 inch between the top of the panel and the bottom of the roof slab which survived at the far range, is similar to the loading on Panel 11R in that the corresponding front wall panel failed. The comparison between computed response and values is shown in Figure 3.18. The computed values are greater than recorded. However, the record may be in error due to failure of the wire clamp.

Panel 14R. Poor agreement was obtained between computed and recorded response values for Panel 14R, an 8-inch reinforced-concrete wall at the near range (Figure 3.19). Both the computed and recorded values indicated virtually no plastic action of the panel, therefore a lower than assumed materials strength would not result in much closer agreement. It has been found that the type of deflection gage which was used is not satisfactory for measuring small displacement, having a lower limit of about 0.50 inch and an accuracy of  $\pm 0.0625$  inch. Since the peak recorded deflection was only 0.21 inch it is possible that the actual values were greater.

The corresponding panel also survived at the far range.

Panel 15R. The comparison between computed and recorded response for Panel 15R, an 8-inch-reinforced-brick wall at the far range (Figure 3.20) was extremely good. The corresponding panel at the near range had a recorded displacement of 4.5 inches (Figure 3.21). Since permanent set was not apparent after the shot, it is assumed that the recorded values are much too large. The maximum computed displacement is 0.41 inch.

The following discussion concerns those curtain wall panels of Structures 3.29 a and c, which were not included in the preceding evaluation of instrumented panels.

Panels 2F, 5F, 8F. Panel 2F was an 8-inch-block wall; Panel 5F and Panel 8F were 4-inch-brick and 4-inch-block. It has been assumed that the composite panels, because of the ties between the brick and block, would behave as a unit. Since the capacities of the curtain wall panels have been based upon the strength of the masonry mortar, the 8-inch-block panel is assumed to have essentially the same resistance function as the 8-inch composite panels. Panels 2F, 5F and 8F failed at both ranges. Figure 3.10, showing the deflection functions for Panel 11F, a 4-inch-brick and 4-inch-block wall, at the far range is representative of the behavior of the above panels.

**Panels 3F, 4F, 7F.** Panels 3F and 4F were 4-inch-brick and 8-inch-block walls, and Panel 7F was 12-inch-block. All three panels failed at the near range while only Panel 7F failed at the far range. The failure of Panel 7F at the far range as compared to the survival of Panels 3F and 4F may be partially attributed to the smaller mass of the former. Also, as previously mentioned, a small (10 to 15 percent) increase or decrease in the effective strength of the masonry mortar can often mean the difference between failure or survival of the panel. The deflection functions for the above panels, at the far range, are similar to that shown for Panel 10F in Figure 3.8.

**Panel 6F.** Panel 6F, an 8-inch-brick wall, failed at the near range and survived at the far range. Failure at both ranges was indicated by postshot analyses. The effective strength of the panel was apparently at least 40 percent greater than computed.

**Panel 9F.** Panel 9F, a 4-inch-brick and 8-inch-block wall with a 2-inch cavity between the brick and block courses, failed at both ranges, as indicated by analyses. Failure at the far range could probably have been prevented if the cavity had been omitted.

**Panel 1R.** Panel 1R was a 12-inch-brick wall which survived at both ranges. Postshot analyses for both panels indicated no failure. At the near range, the panel was subjected to interior pressures because of the failure of the corresponding front wall panel. As previously noted, pressure instrumentation was not provided on the interior of the rear panels, and the use of a modified theoretical interior pressure was necessary to produce consistent results.

**Panels 2R, 5R, 8R, 13R.** Panel 2R was 8-inch block, Panels 5R and 8R were 4-inch-brick and 4-inch-block, and Panel 13R was 4-inch-block and 4-inch-tile. The corresponding front wall panels failed at both ranges. All panels survived at the far range, as shown by postshot analyses, while only Panel 5R survived (Panel 8R was on the verge of failure) at the near range. At the near range, analyses predicted failure of all panels. These panels would behave essentially the same as Panel 11R (4-inch-brick and 4-inch-block), which failed at the near range and survived at the far range (Figure 3.17). A slight decrease in the strength of Panel 5R would have resulted in failure at the near range.

**Panels 3R, 4R, 7R.** Panels 3R and 4R were 4-inch-brick and 8-inch-block, and Panel 7R was 12-inch-block. All panels, except 7R at the near range, survived as predicted by postshot analyses. The corresponding front walls failed at the near range, while at the far range, Panels 3F and 4F survived, and Panel 7F failed. Panel 7R at the far range, and all three panels at the near range were subjected to interior pressures as well as exterior pressures. Panel 7R might have survived at the near range if the strength of the masonry mortar had been slightly greater. The behavior of Panel 11R, a 4-inch-brick and 8-inch-block wall (Figure 3.17), which failed at the near range and survived at the far range, is representative of those of the above panels which were subjected to both interior and exterior pressures, while Panel 10R (Figure 3.16) represents the behavior of the panels which were subjected to exterior pressures only.

**Panel 6R.** Panel 6R was an 8-inch-brick wall, which survived at both ranges as indicated by postshot analyses. At the near range, the panel was subjected to both interior and exterior pressures due to failure of the corresponding front wall panel.

**Panel 9R.** Panel 9R was a 4-inch-brick and 8-inch-block wall, with a 2-inch cavity between the brick and block, which survived at both ranges as predicted by postshot analyses. The corresponding front walls failed at both ranges.

**Panel 16R.** Panel 16R consisted of 22-gage corrugated metal on structural-steel girts. The panel failed at the near range and survived at the far range, as indicated by postshot analyses. The supporting girts were insufficient at both ranges.

**Panel 17R.** Panel 17R consisted of corrugated cement asbestos on structural-

steel girts. The panel failed at both ranges as indicated by postshot analyses.

Panel 17R. Panel 17R consisted of corrugated cement asbestos on structural-steel girts. The panel failed at both ranges as indicated by postshot analyses.

Panel 18R. Panel 18R consisted of 2-foot 0-inch-wide precast-concrete channel slabs spanning vertically. The panels failed at the near range and survived at the far range as indicated by postshot analyses. Failure was by splitting rather than flexure.

### 3.2 INTERIOR PARTITION TEST STRUCTURES, 3.29b AND 3.29d

Pressure instrumentation was not provided for Structures 3.29b (6,600 feet from ground zero) and 3.29d (4,350 feet from ground zero), and it has therefore been necessary to analyze the various interior partitions and curtain walls of these structures with theoretical pressures. The results of these analyses, compared to the test results, are presented in this section.

The theoretical pressures on the front walls with windows were computed. The peak value of the theoretical pressures compared very closely to the recorded peak values which were obtained on the windowless structures, 3.29a (6,650 feet from ground zero) and 3.29c (4,450 feet from ground zero). The pressure variation on the front wall depends upon the size of the window opening and the location of the interior partitions. A typical front wall theoretical pressure variation is shown in Figure 3.22. Theoretical pressures on the interior partitions and interior of the rear walls were also computed. The pressure on the front face of interior partitions immediately to the rear of demolished partitions (or front walls) without openings was assumed as side-on plus dynamic pressure. The exterior pressure on the rear walls was taken to be the same as the recorded rear wall exterior pressures of Structures 3.29a and 3.29c. Typical pressures for several of the interior partitions and rear wall panels are shown in Figures 3.23 through 3.36.

Materials compressive strength field data was as follow (References 1, 2, 3):

Masonry mortar (average of three mixes)	3,736 psi
Brick (tested flatwise)	6,128 psi
Hollow load-bearing masonry units (gross section) 4 by 8 by 16	1,590 psi
8 by 8 by 16	1,050 psi
12 by 8 by 16	1,080 psi

The ultimate static compressive strength of plaster (assuming a normal 1:3 mix of gypsum plaster) was taken as 750 psi. The static strength was increased to 1,000 psi to account for rapid rates of strain. The effective masonry mortar unit strength was assumed as 1,000 psi.

A summary of the observed and calculated behavior of the curtain walls and interior partitions is given in Tables 3.2 through 3.5.

Front Curtain Wall Panels. All of the front curtain wall panels with openings survived at both ranges. The windowless front curtain wall panel (Cell No. 10) failed at the near range but survived at the far range. Postshot analyses agreed with the observed behavior for all panels.

Front Interior Partitions. The percentage of openings in the front curtain walls of Cells 2, 3, 5, 7, and 11 through 16, varied from 15 percent in Cell 3 to 57 percent in Cell 2. The front interior partitions of these cells had no openings, and except for Cells 5 and 16, were composed of 4-inch block with 0.75-inch plaster on each face. The front partition of Cell 5 was made up of 0.75-inch plaster on metal lath attached to

TABLE 3.2 Observed and Calculated Behavior of Front Curtain Walls  
Bldgs. 3.29 "b" and "d"

BLDG 3 29	CELL NO	% OPENING			MATERIAL	BEHAVIOR		REMARKS
		FRONT WALL	FRONT PART	REAR PART		OBSERVED	CALCULATED	
b	1	19	13	0	4" brick + 6" block	No Failure	No Failure	
d	1	19	13	0	do	do	do	
b	2	17	0	0	do	do	do	
d	2	17	0	0	do	do	do	
b	3	15	0	0	do	do	do	
d	3	15	0	0	do	do	do	
b	4	19	-	0	do	do	do	
d	4	19	-	0	do	do	do	
b	5	19	0	0	do	do	do	
d	5	19	0	0	do	do	do	
b	6	19	35	35	do	do	do	
d	6	19	35	35	do	do	do	
b	7	19	0	0	do	do	do	
d	7	19	0	0	do	do	do	
b	8	19	0	0	do	do	do	
d	8	19	0	0	do	do	do	
b	9	19	13	13	4" brick + 6" block	No Failure	No Failure	
d	9	19	13	13	do	do	do	
b	10	0	0	0	do	do	do	
d	10	0	0	0	do	Failed	Failed	
b	11	19	0	13	do	No Failure	No Failure	
d	11	19	0	13	do	do	do	
b	12	19	0	0	do	No Failure	No Failure	
d	12	19	0	0	do	do	do	
b	13	19	0	0	do	do	do	
d	13	19	0	0	do	do	do	
b	14	19	0	-	do	do	do	
d	14	19	0	-	do	do	do	
b	15	31	0	0	do	do	do	
d	15	31	0	0	do	do	do	
b	16	19	0	0	do	do	do	
d	16	19	0	0	do	do	do	



TABLE 3.3 Observed and Calculated Behavior of Front Interior  
Partitions - Bldgs 3.29 "b" and "d"

BLDG 3.29	CELL NO.	% OPENING			MATERIAL	BEHAVIOR		REMARKS
		FRONT WALL	FRONT PART	REAR PART		OBSERVED	CALCULATED	
b	1	19	13	0	4" block; 0.75" plaster E.F.	No Failure	No Failure	Door blown out
d	1	19	13	0	do	Failed	Failed	
b	2	57	0	0	do	Failed	Failed	
d	2	57	0	0	do	do	do	
b	3	15	0	0	do	do	do	
d	3	15	0	0	do	do	do	
b	4	19	-	0	2"x4" studs-metal lath-plaster	do	do	
d	4	19	-	0				
b	5	19	0	0				
d	5	19	0	0				
b	6	19	35	35	Hauserman Type R-Steel	do	do	
d	6	19	35	35	do	do	do	
b	7	19	0	0	4" block; 0.75" plaster E.F.	do	do	
d	7	19	0	0	do	do	do	
b	8	19	0	0	8" block; 0.75" plaster E.F.	No Failure	No Failure	Door blown out
d	8	19	0	0	do	Failed	Failed	
b	9	19	13	13	4" block; 0.75" plaster E.F.	No Failure	No Failure	
d	9	19	13	13	do	Failed	Failed	
b	10	0	0	0	do	No Failure	No Failure	Short span did not fail
d	10	0	0	0	do	Failed	Failed	
b	11	19	0	13	do	do	do	
d	11	19	0	13	do	do	do	
b	12	19	0	0	do	do	do	
d	12	19	0	0	do	do	do	
b	13	19	0	0	do	do	do	
d	13	19	0	0	do	do	do	
b	14	19	0	-	do	do	do	wire lath in plaster
d	14	19	0	-	do	do	do	
b	15	31	0	0	do	do	do	
d	15	31	0	0	do	do	do	
b	16	19	0	0	2" plaster - metal lath	do	do	do
d	16	19	0	0	do	do	do	

TABLE 2.4 Observed and Calculated of Rear Interior Partitions - Bldg. 3.29 "b" and "d"

BLDG 329	CELL NO.	% OPENING			MATERIAL	BEHAVIOR		REMARKS
		FRONT WALL	FRONT PART	REAR PART		OBSERVED	CALCULATED	
b	1	12	13	0	4" block; 0.75" plaster F.F.	Failed	Failed	
d	1	12	13	0	do	do	do	
b	2	57	0	0	do	do	do	
d	2	57	0	0	do	do	do	
b	3	15	0	0	do	do	do	
d	3	15	0	0	do	do	do	
b	4	19	-	0	do	do	do	
d	4	19	-	0	do	do	do	
b	5	19	0	0	2"x4" studs-metal lath-plaster	do	do	
d	5	19	0	0	do	do	do	
b	6	19	35	35	Hauserman Type K-steel	do	do	
d	6	19	35	35	do	do	do	
b	7	19	0	0	4" block; 0.75" plaster F.F.	do	do	
d	7	19	0	0	do	do	do	
b	8	19	0	0	8" block; 0.75" plaster F.F.	No Failure	No Failure	
d	8	19	0	0	do	Failed	Failed	
b	9	19	13	13	4" block; 0.75" plaster E.F.	No Failure	No Failure	
d	9	19	13	13	do	do	do	
b	10	0	0	0	do	do	do	
d	10	0	0	0	do	Failed	Failed	
b	11	19	0	13	do	No Failure	No Failure	Rear partitions perpen- dicular to front parti- tion. Door blown in.
d	11	19	0	13	do	do	do	
b	12	19	0	0	do	Failed	Failed	
d	12	19	0	0	do	do	do	
b	13	19	0	0	do	do	do	
d	13	19	0	0	do	do	do	
b	14	19	0	-	4" block; 0.75" plaster E.F.			
d	14	19	0	-				
b	15	31	0	0	do	do	do	
d	15	31	0	0	do	do	do	
b	16	19	0	0	2" plaster - metal lath	do	do	
d	16	19	0	0	do	do	do	

TABLE 3.5 Observed and Calculated Behavior of Rear Curtian Walls - Bldg. 3.29 "b" and "d"

BLDG. 3.29	CELL NO.	% OPENING			MATERIAL	BEHAVIOR		REMARKS
		FRONT WALL	FRONT PART.	REAR PART.		OBSERVED	CALCULATED	
b	1	19	13	0	4" brick + 8" block	No Failure	No Failure	Wall on verge of collapse
d	1	19	13	0	do	do	do	
b	2	57	0	0	do	do	do	
d	2	57	0	0	do	Failed	do	
b	3	15	0	0	do	No Failure	do	
d	3	15	0	0	do	do	do	
b	4	19	-	0	do	do	do	
d	4	19	-	0	do	do	do	
b	5	19	0	0	do	do	do	
d	5	19	0	0	do	Failed	do	
b	6	19	35	35	do	No Failure	do	
d	6	19	35	35	do	do	do	
b	7	19	0	0	do	do	do	
d	7	19	0	0	do	do	do	
b	8	19	0	0	do	do	do	
d	8	19	0	0	do	do	do	
b	9	19	13	13	4" brick + 8" block	No Failure	No Failure	
d	9	19	13	13	do	do	do	
b	10	0	0	0	do	do	do	
d	10	0	0	0	do	do	do	
b	11	19	0	13	do	do	do	
d	11	19	0	13	do	do	do	
b	12	19	0	0	do	do	do	Wall on verge of collapse
d	12	19	0	0	do	Failed	do	
b	13	19	0	0	do	No Failure	do	
d	13	19	0	0	do	Failed	do	
b	14	19	0	-	do	No Failure	do	
d	14	19	0	-	do	do	do	
b	15	31	0	0	do	do	do	
d	15	31	0	0	do	Failed	do	
b	16	19	0	0	do	No Failure	do	
d	16	19	0	0	do	Failed	do	

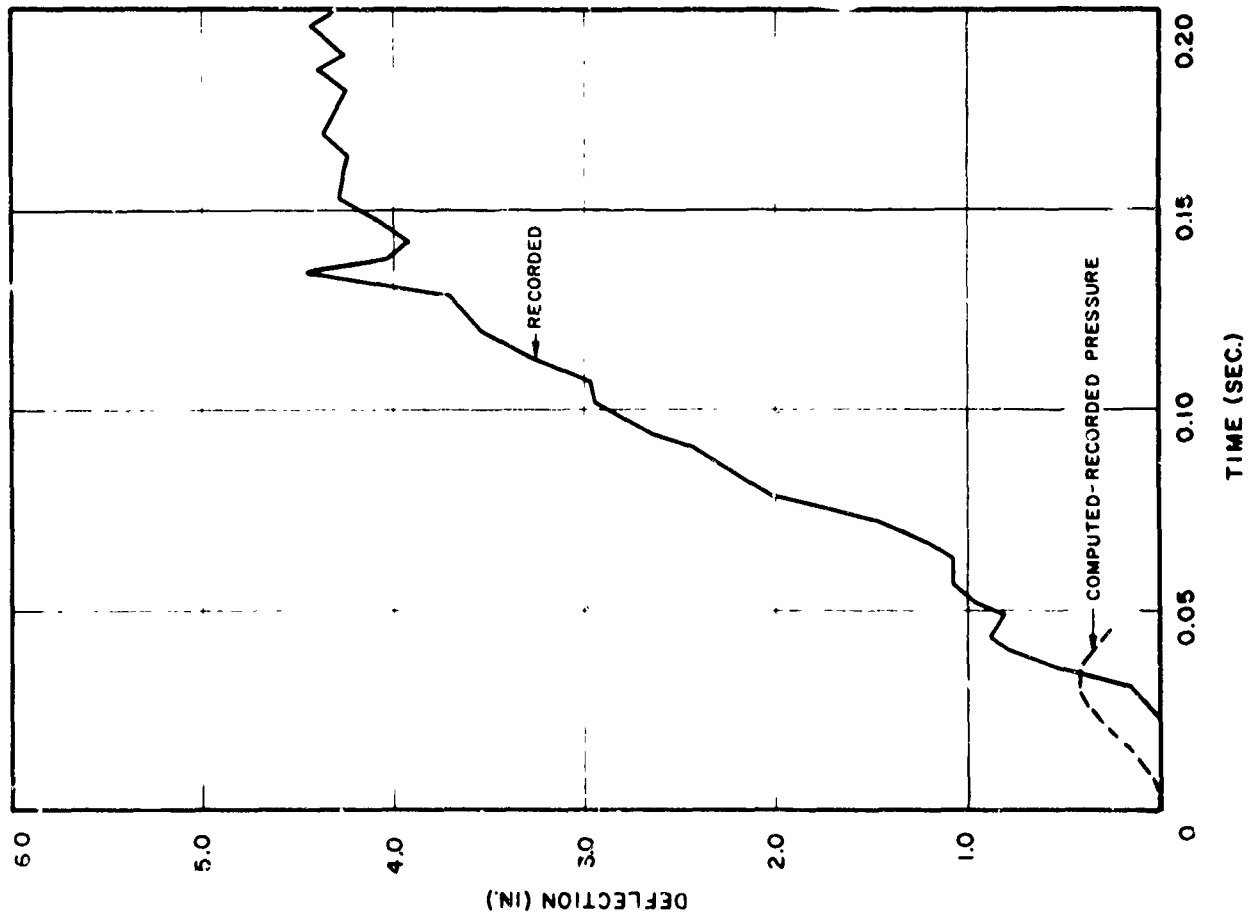


Fig. 3.21 Comparison of Recorded and Computed Deflections - Bldg. 3.29c - Panel 15R

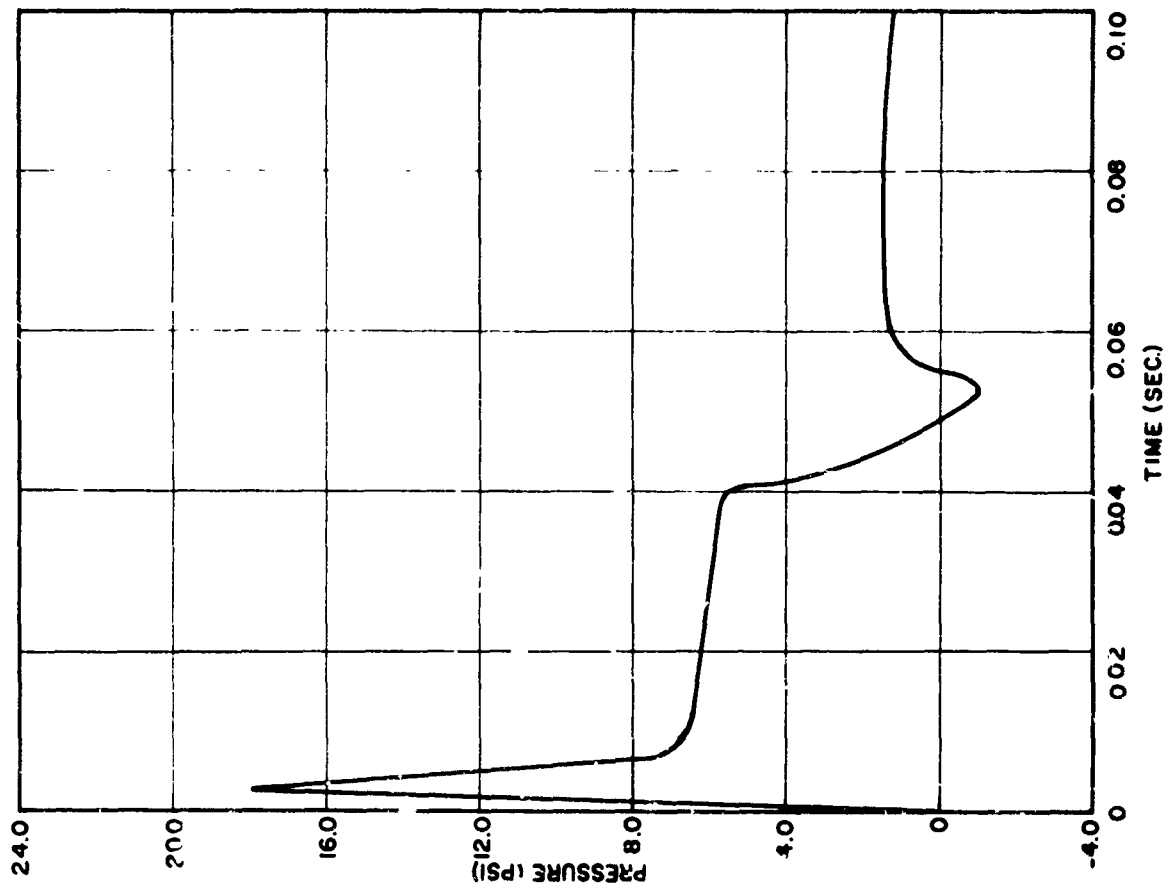


Fig. 3.22 Theoretical Front Wall Pressure - Bldg. 3.29d - Cell No. 1

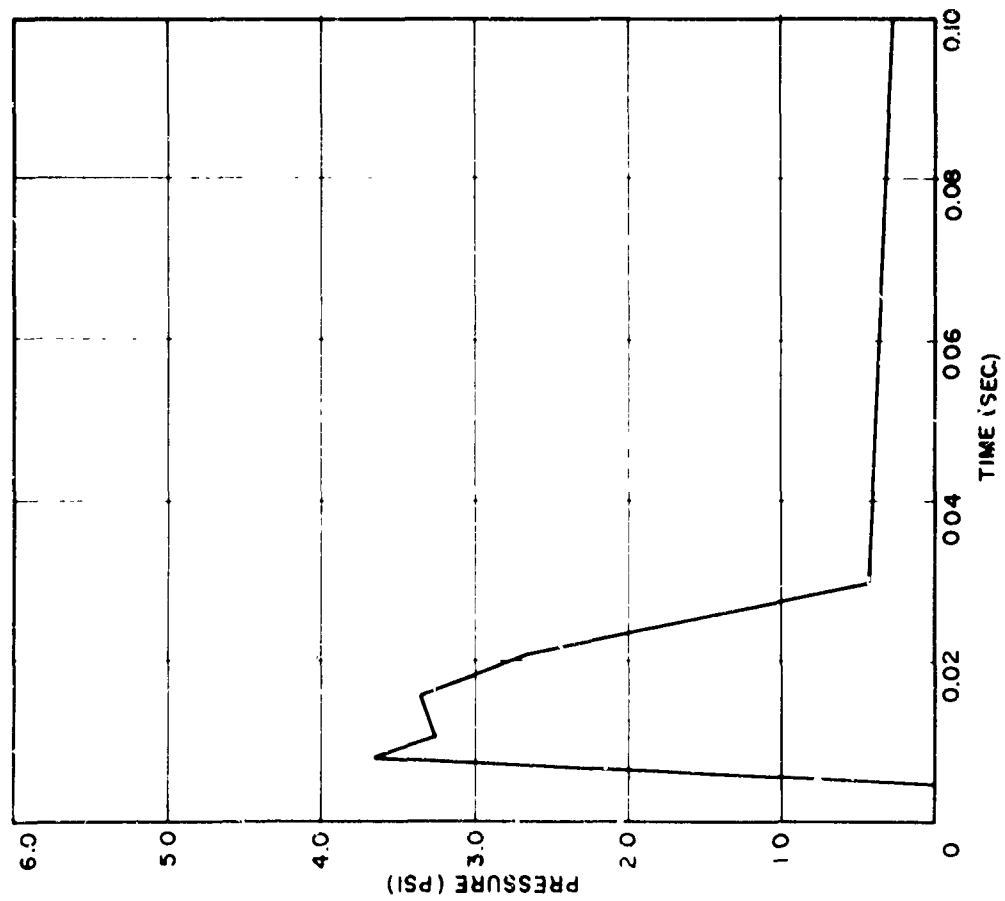


Fig. 3.23 Theoretical Front Partition Pressure -  
Bldg. 3.29b - Cell No. 1

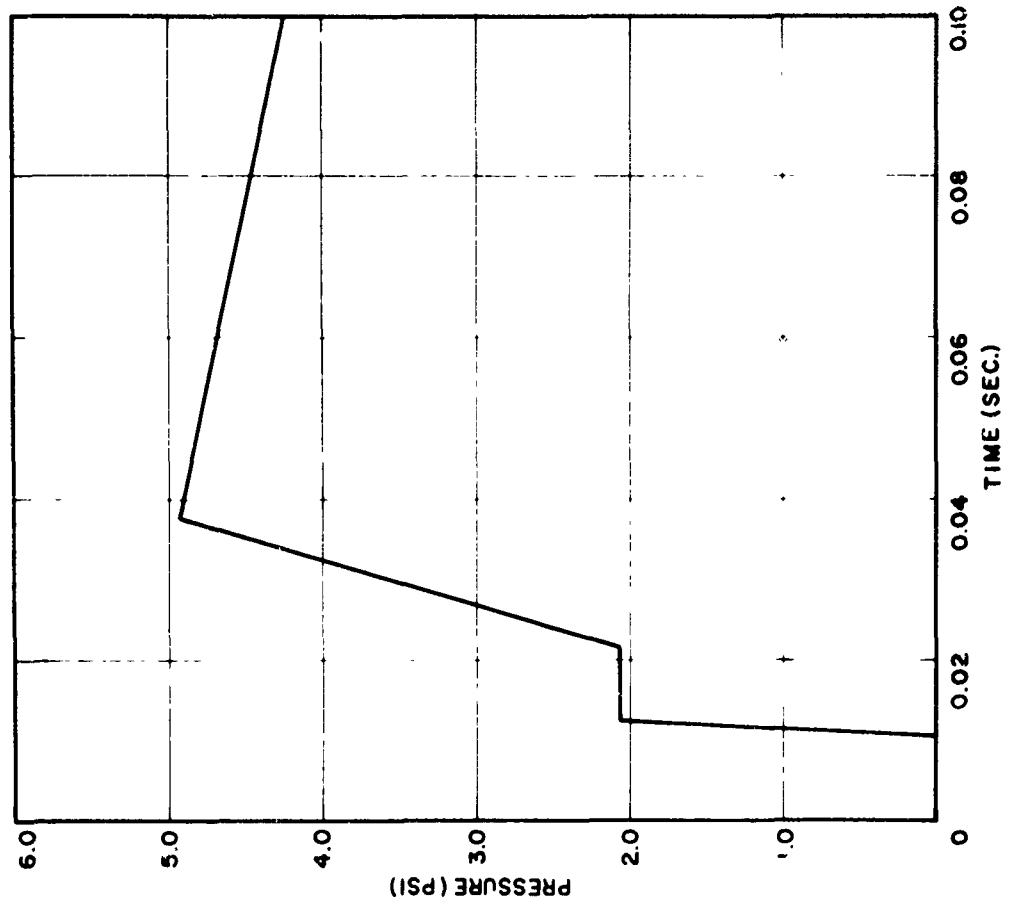


Fig. 3.24 Theoretical Rear Partition Pressure -  
Bldg. 3.29b - Cell No. 1

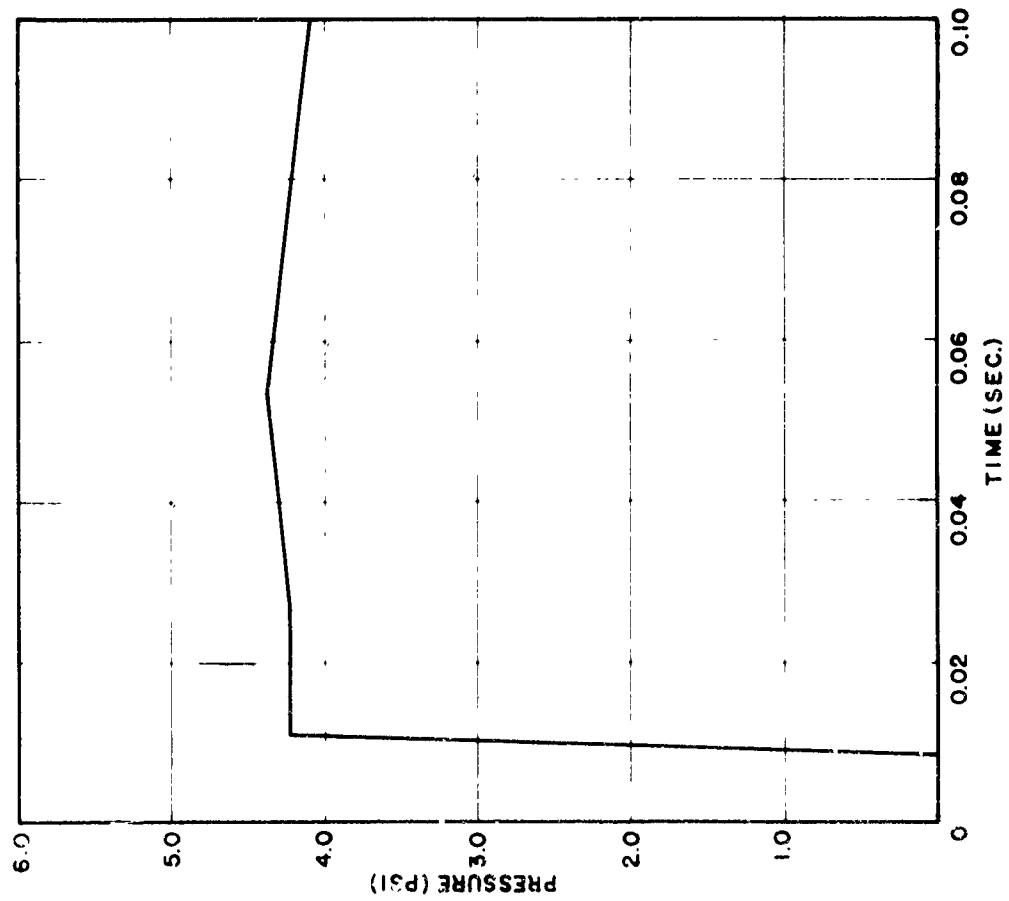


Fig. 3.25 Theoretical Front Partition Pressure -  
Bldg. 3.29b - Cell No. 3

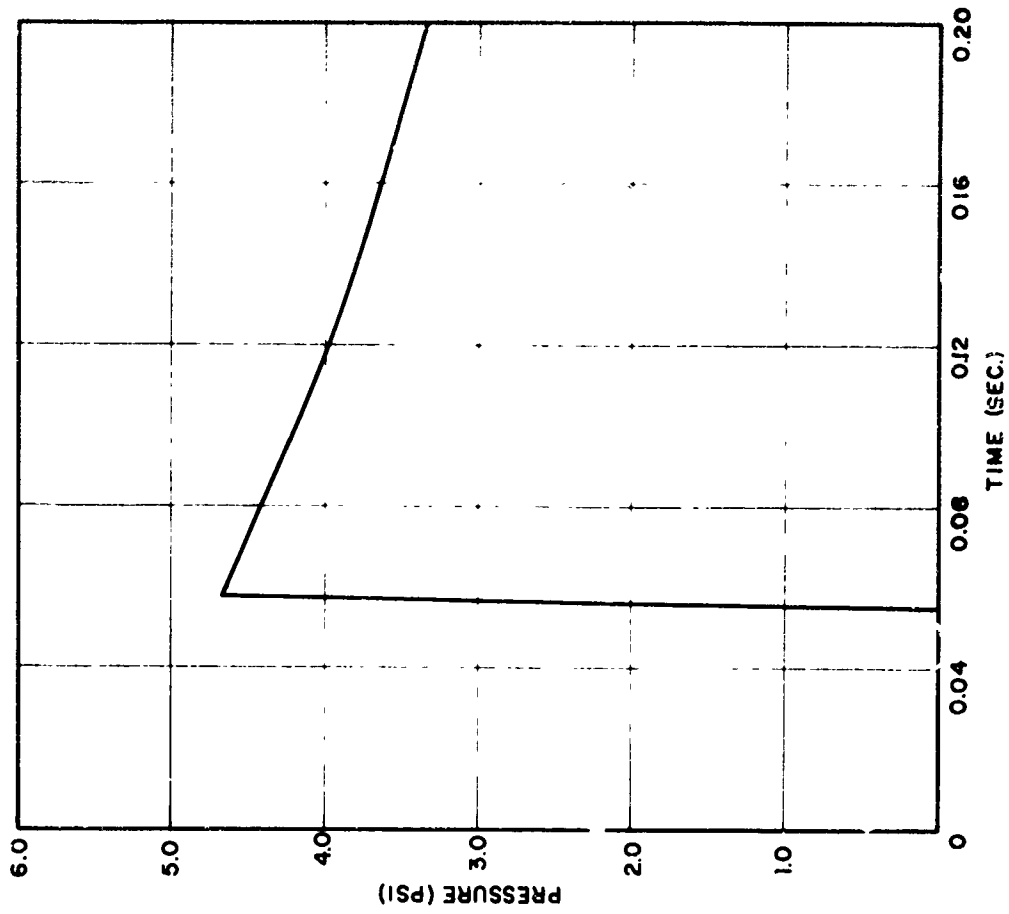


Fig. 3.26 Theoretical Rear Partition Pressure -  
Bldg. 3.29b - Cell No. 3

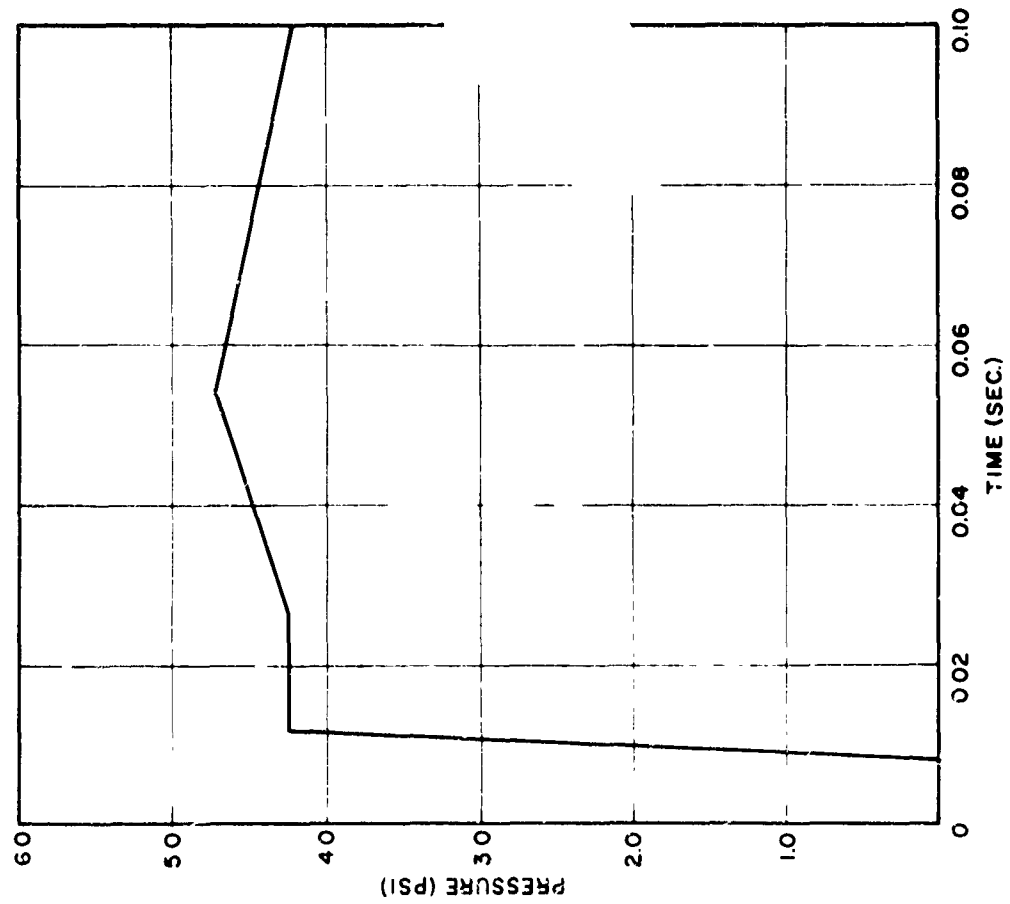


Fig. 3.27 Theoretical Front Partition Pressure -  
Bldg. 3.29b - Cell No. 8

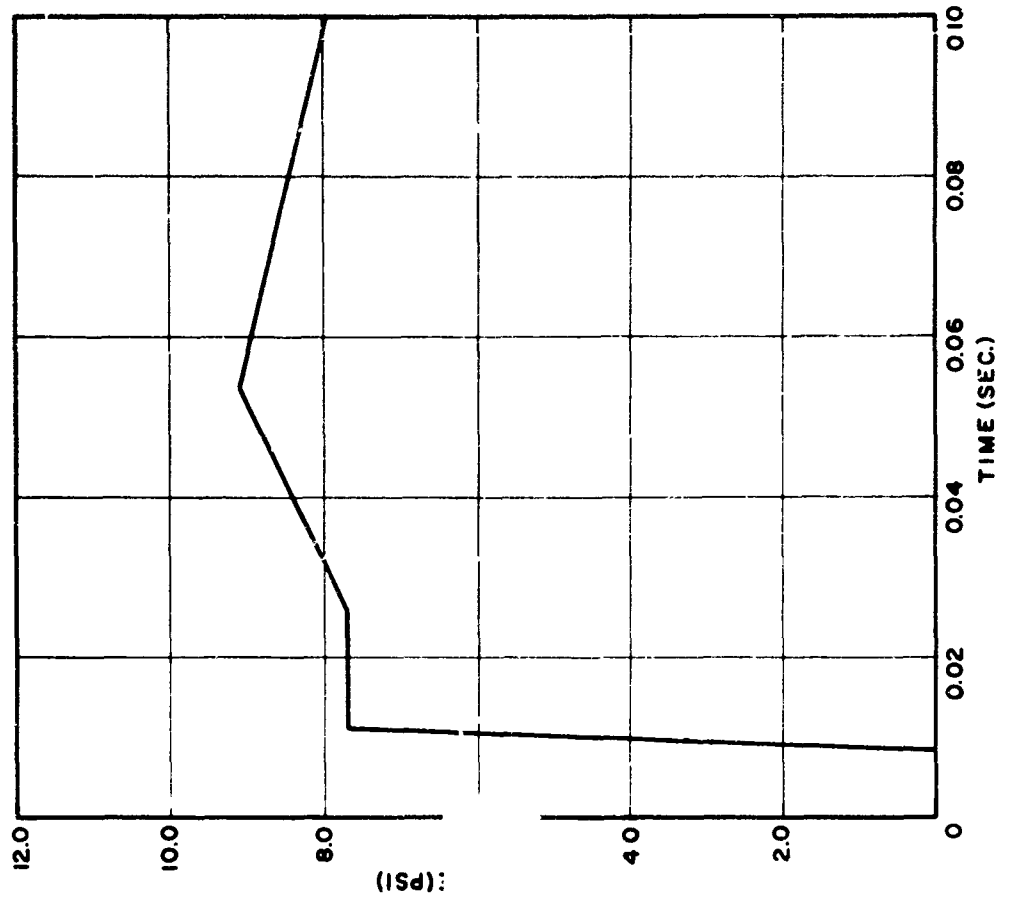


Fig. 3.28 Theoretical Front Partition Pressure -  
Bldg. 3.29d - Cell No. 8

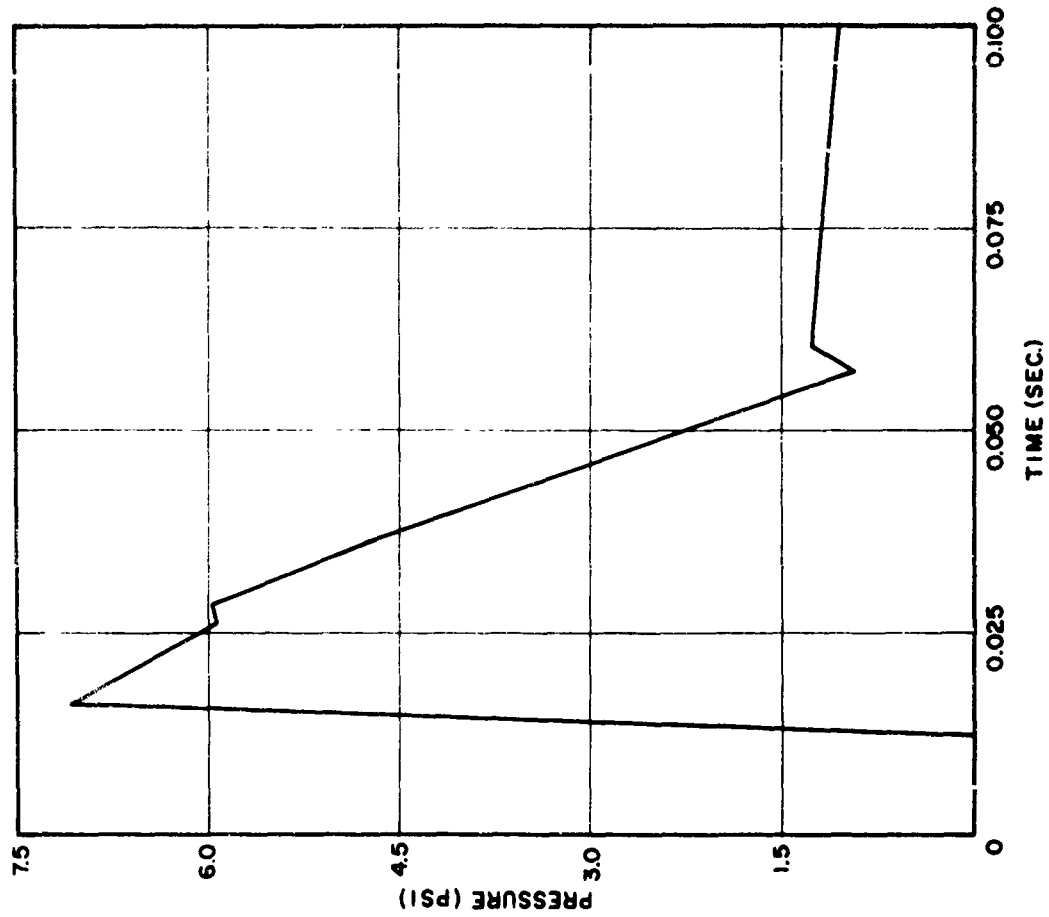


Fig. 3.30 Theoretical Front Partition Pressure -  
Bldg. 3.29d - Cells No. 6 & 9

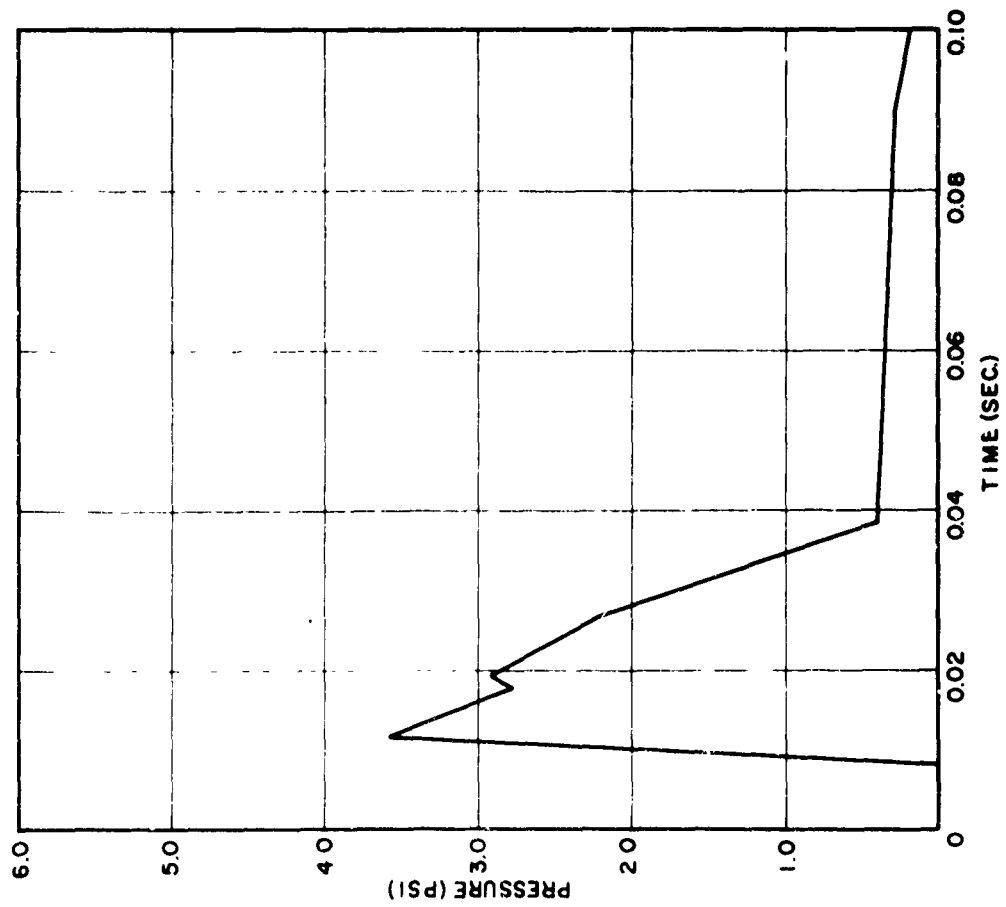


Fig. 3.29 Theoretical Front Partition Pressure -  
Bldg. 3.29b - Cells No. 6 & 9



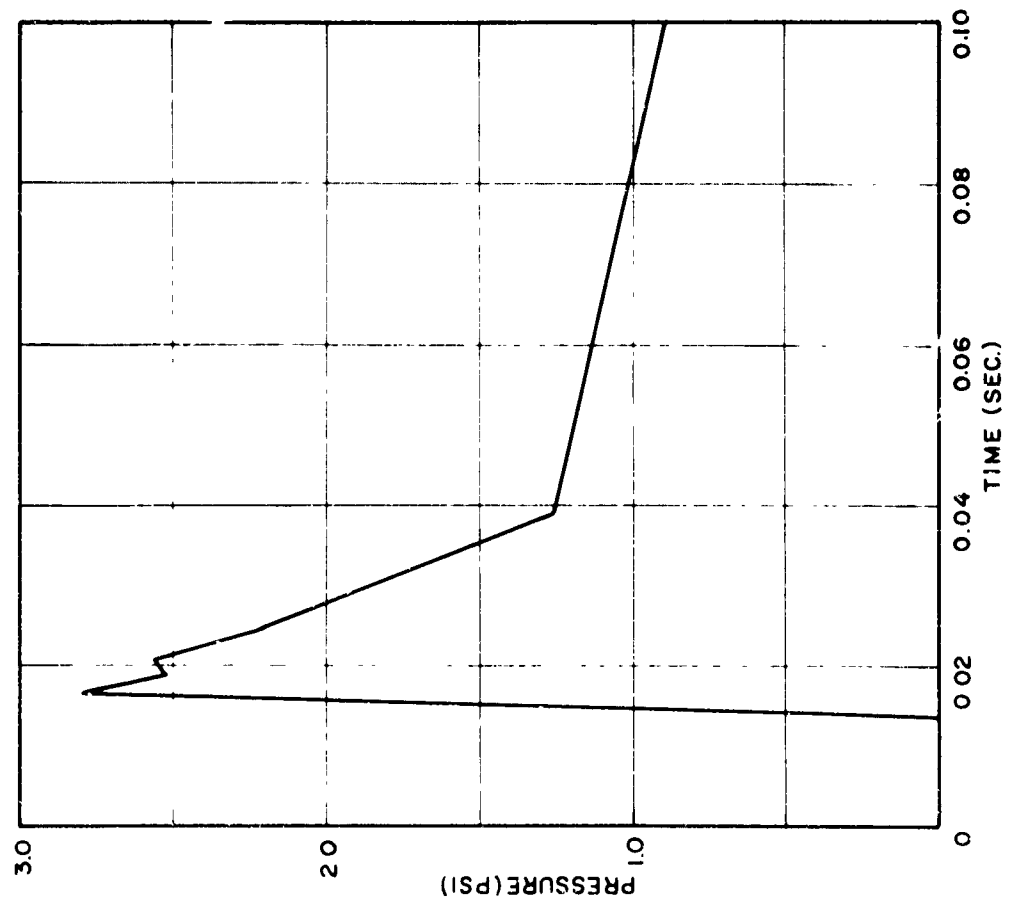


Fig. 3.31 Theoretical Rear Partition Pressure -  
Eldg. 3.29d - Cell No. 9

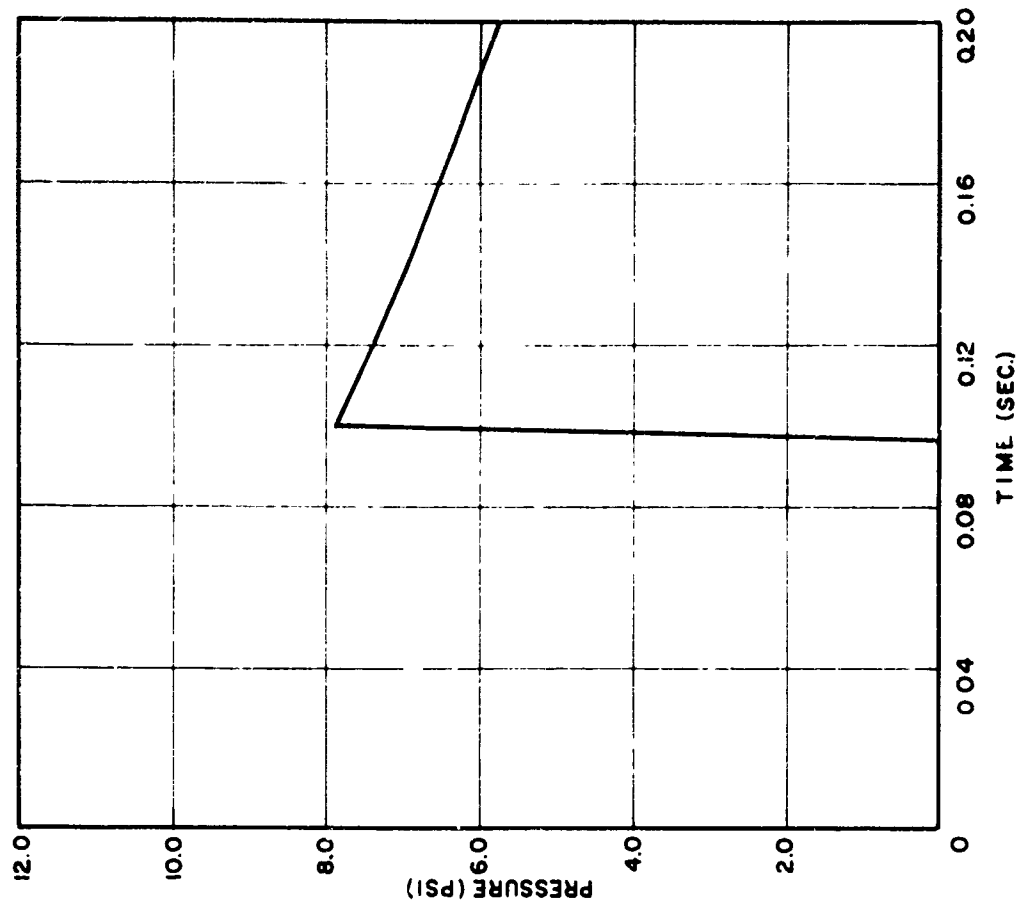


Fig. 3.32 Theoretical Rear Partition Pressure -  
Eldg. 3.29d - Cell No. 10

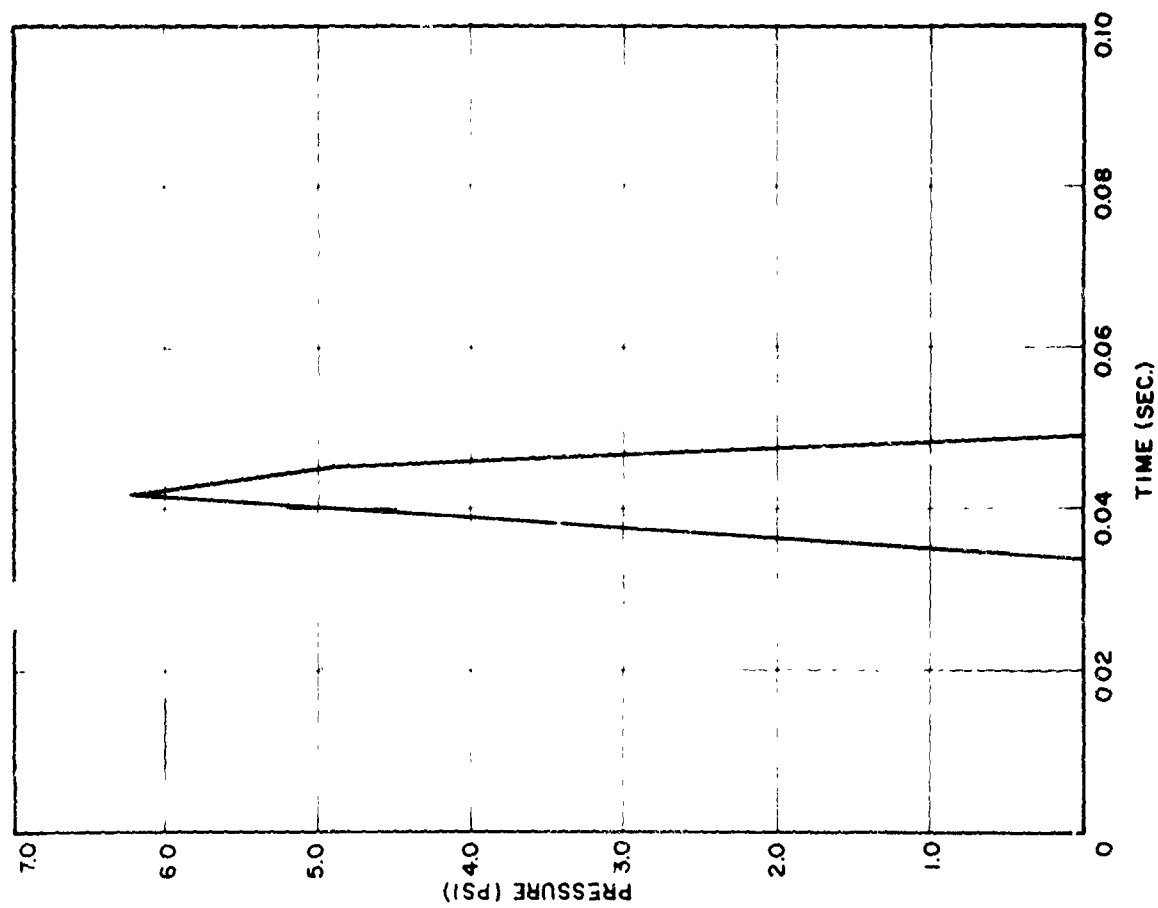


Fig. 3.33 Theoretical Rear Partition Pressure -  
Eldg. 3.29d - Cell No. 11

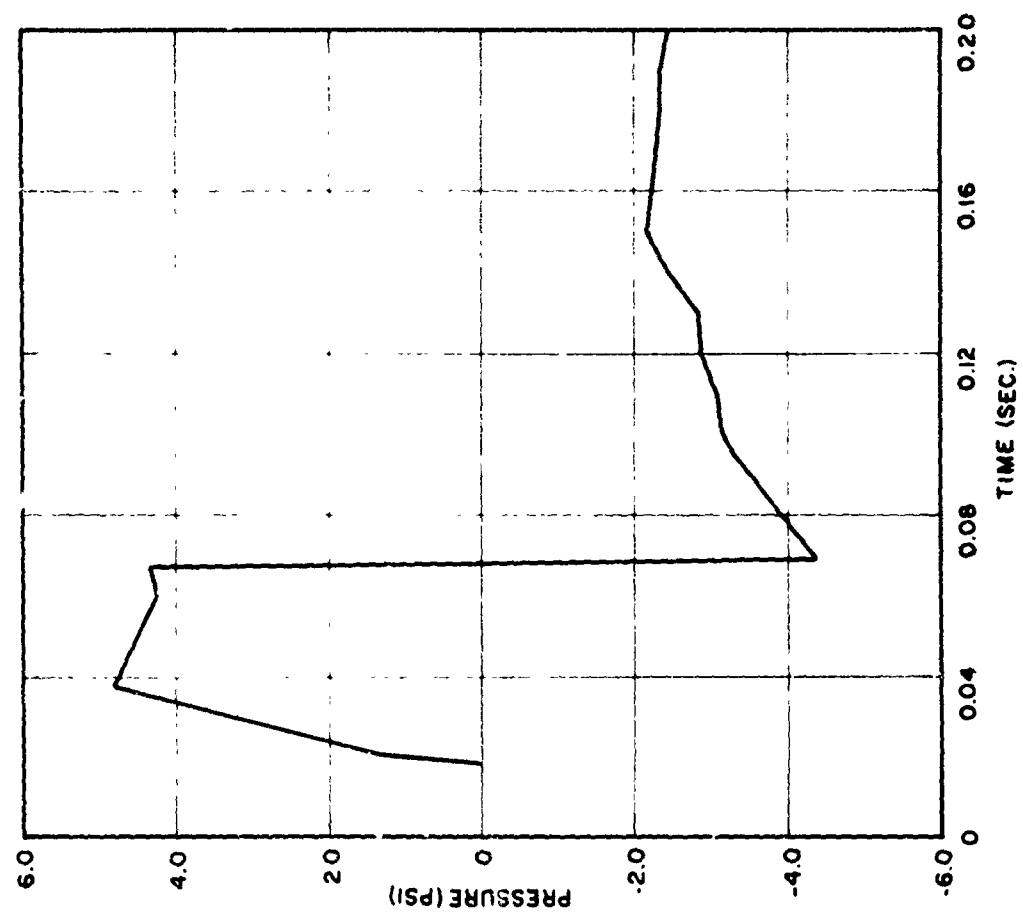


Fig. 3.34 Assumed Rear Wall Net Pressure -  
Eldg. 3.29d - Cell No. 1

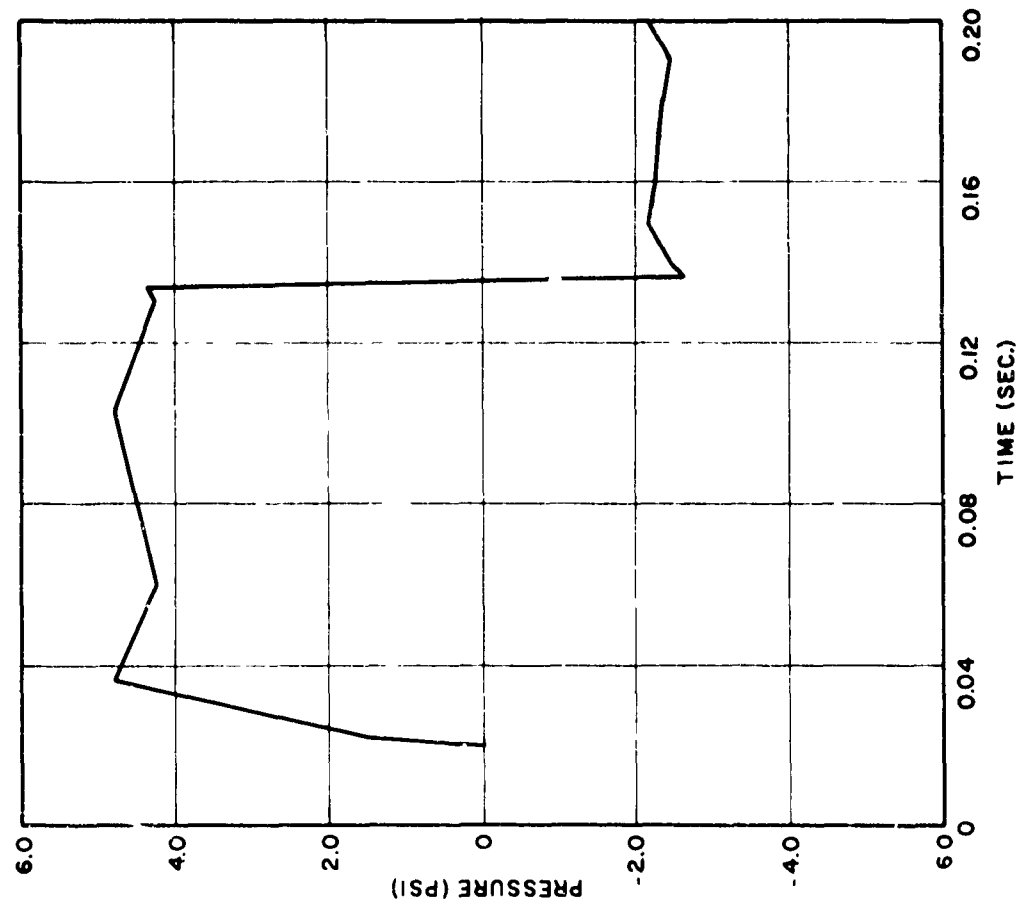


Fig. 3.35 Assumed Rear Wall Net Pressure -  
Bldg. 3.29d - Cell No. 10

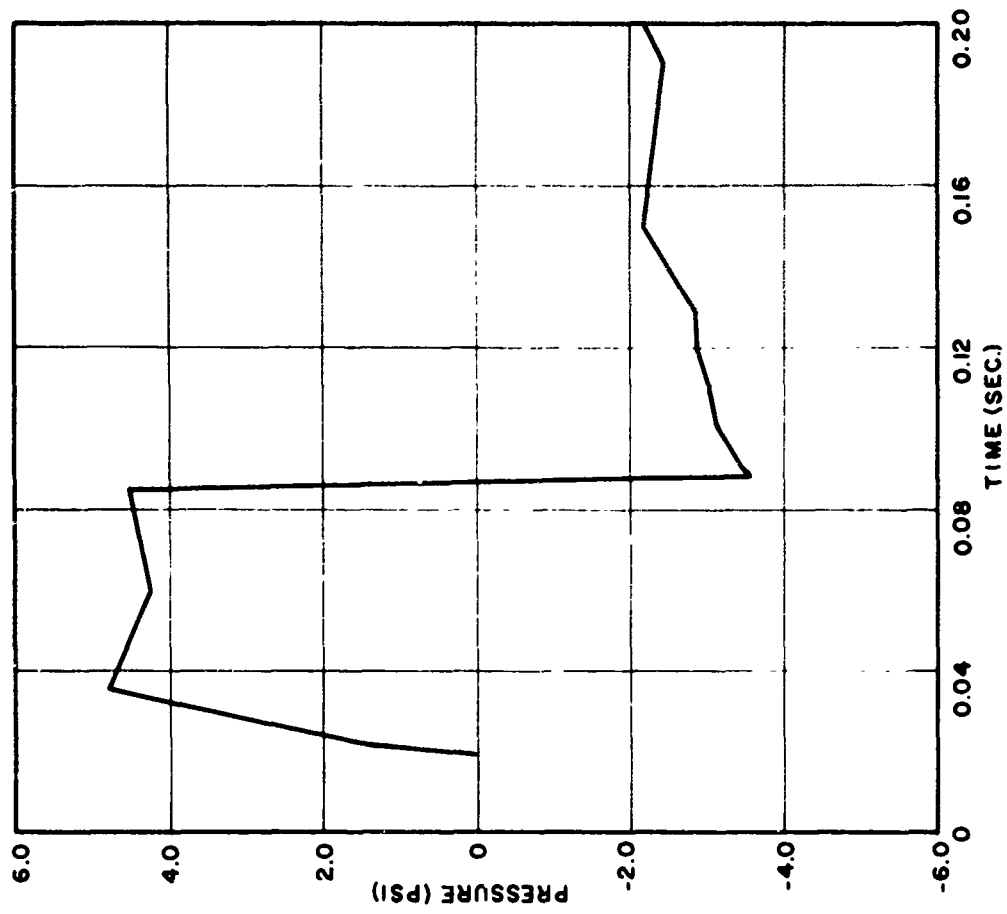


Fig. 3.36 Assumed Rear Wall Net Pressure -  
Bldg. 3.29d - Cells No. 7, 12, 13, & 15

both sides of 2-inch-by-4-inch studs, and the front partition of Cell 16 was made up of 2-inch plaster on metal lath. The blast loading on these partitions was a minimum for Cell 3 and a maximum for Cell 2. The front partitions failed at both ranges, which agreed with the postshot analyses.

The front partition of Cell 8 had no openings and was composed of 8-inch block with 0.75-inch plaster on each face. The front curtain wall contained a 19-percent window opening. The partition survived at the far range and failed at the near range as indicated by the posttest analyses.

The front partition of Cell 10 had no openings and was composed of 4-inch block with 0.75-inch plaster on each face. The load on the partition, after failure of the windowless front wall, was assumed as side-on plus dynamic pressure. The partition, as predicted by analyses, survived at the far range and failed at the near range.

The front partitions of Cells 1 and 9 were 4-inch block with 0.75-inch plaster on each face with a standard type door at the center of each partition. At the far range, the doors were blown in, relieving the pressures on the front face of the partitions, which survived. At the near range, the partitions were destroyed. The computed action of the partitions was the same as the observed behavior.

The front partition of Cell 6 was a Hauserman Type R-steel partition with a 35-percent glazed center section. The panel was torn loose from the nailed inserts and blown to the rear of the cell at both ranges. Analyses predicted failure at both ranges.

**Rear Interior Partitions.** The rear partitions in Cells 2, 3, 5, 7, 12, 13, 15 and 16 had no openings and, except for the partitions in Cells 5 and 16, were the same as the front interior partitions, i.e., 4-inch block with 0.75-inch plaster on each face. The rear partition of Cell 5 was made up of 0.75-inch plaster on metal lath attached to both sides of 2-inch-by-4-inch studs. Cell 16 had interior partitions made up of 2-inch plaster on metal lath. All partitions failed as indicated by analyses.

The front and rear partitions in Cell 8 had no openings and were composed of 8-inch block with 0.75-inch plaster on each face. The rear partition failed at the near range as shown by analysis. At the far range the front partition survived and therefore the rear partition was not loaded.

The walls and both partitions of Cell 10 had no openings. The partitions were 4-inch block with 0.75-inch plaster on each face. The rear partition failed at the near range as predicted, while at the far range the rear partition was not loaded due to the survival of the front partition.

The partitions of Cells 1 and 9 were 4-inch block with 0.75-inch plaster on each face. Each of the front walls of these cells had a 19-percent opening. The partition openings for the front and rear partitions respectively were—Cell 1: 13 percent, 0 percent; Cell 9: 13 percent, 13 percent. The rear partition of Cell 1 failed at both ranges while the rear partition of Cell 9, because of the relief afforded by the presence of the door openings, survived at both ranges.

The partition of Cell 4 was 4-inch block with 0.75-inch plaster on each face. Since there was no front partition, the rear partition behaved essentially the same as the front partitions of Cells 7, 12, 13 and 15. Failure, as indicated by analyses, occurred at both ranges.

The partitions of Cell 6 were Hauserman Type R-steel with 35 percent glazed area. The rear panel failed (pushed to rear of cell) at both ranges as predicted.

The partitions of Cell 11 were 4-inch block with 0.75-inch plaster on each face. The rear partition had a door opening which relieved the blast pressures and the rear partition survived as predicted at both ranges.

**Rear Curtain Walls.** The rear curtain walls were windowless and consisted

of 4-inch brick and 8-inch block. At the far range, all of the rear walls survived. At the near range, failure of the rear walls occurred in Cells 2, 5, 12, 13, 15 and 16; the remaining ten walls survived although those in Cells 3 and 7 were on the verge of failure. Analysis indicated that all of the rear walls would survive at both ranges. Failure of six of the rear walls at the near range would seem to indicate that the interior pressures were somewhat higher than assumed.

### 3.3 FUNDAMENTAL FREQUENCY COMPARISONS

Fundamental frequency data (Reference 6) was taken in the field for the majority of the curtain walls of Structures 3.29 a, b, c and d. A comparison between the preshot fundamental frequencies versus the computed fundamental frequencies is shown in Tables 3.6 and 3.7. Because of the wide variation of the measured frequencies for similar walls a comparison between computed and averaged recorded frequencies for similar walls is also shown. A comparative study was made between the extent of damage and the ratio of postshot to preshot (fundamental) frequencies of the walls; but no correlation could be found.

A sample computation showing the method (Reference 7) of obtaining fundamental frequencies is shown below for the front and rear wall panels in Cell No. 7 of Buildings 3.29a and c (12-inch cinder-block panel, 10 feet 0 inches high by 16 feet 0 inches wide):

$$f = \sqrt{\frac{\pi^2 EI}{4mL^3}}$$

Where: E = modulus of elasticity of panel = 1,080 kips/in<sup>2</sup>

I = moment of inertia = 1,575 in<sup>4</sup>

m = mass of panel = 0.0218 kip-sec<sup>2</sup>/ft

L = span of panel = 10 ft 0 in

All values are based upon a 1 ft 0 in wide strip

$$\therefore f = \sqrt{\frac{\pi^2 (1080) (1575)}{4(0.0218) (144) (1000)}} = 36.6 \text{ cps}$$

### 3.4 CONCLUSIONS AND RECOMMENDATIONS

Several overall conclusions may be drawn directly from the observed damage under the conditions of this test. These conclusions are valid for the test structures and other one-story structures of similar size and construction.

1. Curtain walls with as low as 15 percent window openings will remain in place without serious damage under pressures which will completely destroy solid curtain walls of similar construction.

2. Nonload-bearing interior partitions without openings, of the type most commonly used in building construction, may be expected to fail completely when exposed behind curtain walls having as low as 15 percent window openings, before the curtain walls are damaged to the point of collapse. Openings in interior partitions greatly reduce the probability of their collapse.

3. Debris from the destruction of curtain walls and partitions facing the blast may

TABLE 3.6 Summary of Pre Shot Fundamental Frequencies of Front & Rear Walls - Bldgs. 3.29 "a" and "c"

CELL NO	MATERIAL	RECORDED FREQUENCY				AVERAGE ** FREQUENCY	COMPUTED FREQUENCY
		BLDG 3 29a		BLDG 3 29c			
		FRONT	REAR	FRONT	REAR		
1	12" brick	51.7	56.0	37.5	56.1	40.3	60.5
2	8" cinder block	33.4	35.9	68.8*	34.7	34.7	24.5
3	4" brick + 8" cinder block	42.6	44.0	41.7	40.3	43.8	47.8
4	4" brick + 8" cinder block	35.1	33.0	26.5	31.2	43.8	47.8
5	4" brick + 8" cinder block	32.2	30.2	23.2	25.1	43.8	47.8
6	8" brick	36.4	34.7	30.4	32.2	33.4	42.7
7	12" cinder block	38.3	48.4	45.8	43.5	42.5	36.6
8	4" brick + 4" cinder block	26.7	30.3	22.7	27.6	25.7	33.3
9	4" brick+2" cavity-8" cinder block	18.7	25.6	26.6	30.6	25.4	23.0
10	4" brick + 8" cinder block	47.5	42.5	23.6	41.6	43.8	47.8
11	4" brick + 4" cinder block	21.6	28.0	22.6	25.7	25.7	33.3
12	4" brick+8" cinder block, 0.75" space	17.2*	19.5*	14.2*	25.3*	43.8	47.8
13	4" brick + 4" clay tile	35.6	35.1	----	34.5	35.4	30.1
14	8" reinforced concrete	61.6	39.1	75.0	68.8	61.1	67.0
15	12" reinf. brick - 8" reinf. brick	----	----	32.9	26.6	32.9 26.6	34.3 22.6
16	22 gauge corrugated metal	----	----	----	----	----	----
17	corrugated transite	----	----	----	----	----	----
18	precast reinf. concrete channels	----	24.0	----	----	24.0	36.3

\* Value not included in average.

\*\* Average of measured fundamental frequencies of all similar windowless walls - Bldgs. 3.29 "a," "b," "c," & "d."

TABLE 3.7 Summary of Pre Shot Fundamental Frequencies of Front & Rear Walls - Bldgs. 3.29 "b" and "d"

CELL NO.	MATERIAL	RECORDED FREQUENCY		AVERAGE ** FREQUENCY	COMPUTED FREQUENCY	RECORDED FREQUENCY		AVERAGE FREQUENCY	COMPUTED FREQUENCY
		3.29b	3.29d			3.29b	3.29d		
		REAR WALL				FRONT WALL			
1	4" brick + 8" cinder block	36.1	38.2	43.8	47.8	36.1	37.0	35.3*	47.8
2	do	46.5	53.2	do	do	----	----	----	----
3	do	50.8	50.0	do	do	35.4	33.3	35.3*	47.8
4	do	58.3	52.2	do	do	33.4	34.7	do	do
5	do	55.3	50.0	do	do	33.3	36.6	do	do
6	do	41.1	43.6	do	do	34.2	35.1	do	do
7	do	47.1	55.7	do	do	38.4	33.7	do	do
8	do	50.0	59.0	do	do	38.2	32.7	do	do
9	do	37.5	34.3	do	do	36.3	39.2	do	do
10	do	54.0	50.0	do	do	54.5	41.6	43.8**	do
11	do	37.5	41.6	do	do	----	33.3	35.3*	do
12	do	56.7	44.4	do	do	35.6	35.5	do	do
13	do	62.5	55.4	do	do	39.7	34.4	do	do
14	do	35.4	37.5	do	do	37.8	33.3	do	do
15	do	45.8	51.9	do	do	30.9	----	do	do
16	do	47.7	50.8	do	do	33.0	37.5	do	do

\* Average of measured fundamental frequencies of all windowed walls - Bldgs. 3.29 "b" & "d".

\*\* Average of measured fundamental frequencies of all similar windowless walls - Bldgs. 3.29 "a," "b," "c," & "d."

be expected to be blown with considerable velocity against the partitions or walls located behind them.

Conclusions and recommendations based upon the evaluation of the test data and records are as follows:

1. Existing analytical procedures for estimating blast loadings on wall and roof panels appear to be satisfactory for most structures; but further study of the blast loading on interior partitions of windowed structures is necessary. No information is available at this time concerning the interior blast loading behind windowless curtain walls or

TABLE 3.8 Maximum Overpressure Which the Various Types of Windowless Test Panels may be Expected to Resist in a One Story Structure (see Conclusion 4 - Section 3.1.4)

TYPE OF WALL	ESTIMATED ALLOWABLE OVERPRESSURE ON THE PANEL PSI
8" reinforced concrete	34
12" reinforced brick	26
12" brick	18
8" reinforced brick	14
8" brick	11
4" brick + 8" block	11
12" block	10
4" brick + 8" block + 0.75" space at top	6+
4" brick + 2" cavity + 8" block	6
8" block	6
4" brick + 4" block	5
precast reinforced channel	4
22 gauge corrugated metal on girts	4
4" brick + 4" tile	3
corrugated transite on girts	< 3
Partitions (without openings) behind windowed (20% or less) curtain walls.	
8" block + 0.75" plaster each face	18*
4" block + 0.75" plaster each face	4*

\* Peak pressure on exterior of front wall.

partitions without openings subsequent to failure of these members. In analyzing the walls and partitions behind the windowless curtain walls and partitions without openings, it was found that fairly good correlation between observed behavior and computed behavior could be obtained by assuming that the interior blast loading was approximately equal

to side-on plus dynamic pressure. A future effort should be made to verify or improve on this assumption.

2. Present methods for determining the response of reinforced concrete and structural steel members have previously been verified both in the field and laboratory. However, the response of unreinforced masonry panels, such as those which were used for this test program, requires further investigation. Studies of restrained unreinforced masonry panels with weak direction spanning, including the effectiveness of masonry ties and variations of mortar strength, would be of considerable value. The results obtained in this test have verified to a fairly good degree, the resistance function for restrained unreinforced masonry panels proposed by Ammann and Whitney. The resistance functions for solid and hollow unreinforced masonry panels which were used for the test panels are shown in Figures 3.37 and 3.38 respectively. The resistance of a composite wall panel (with sufficient masonry ties), made up of a brick wall and a hollow block wall is assumed to be the same as that of a hollow block wall panel of the same total thickness as the composite panel, with a flange thickness equal to that of the actual hollow member. The resistance of a cavity wall panel with ties is taken as the sum of the resistances of the panels on each side of the cavity. The resistance of restrained unreinforced masonry walls is a function of the vertical thrust which is developed by the compressive strains which occur as the wall deflects. The presence of a small joint space at the top of the wall obviously reduces the panel capacity, particularly when the ratio of height to thickness is large. For example, a 10-foot wall, 4 inches thick, with a 0.50-inch space at the top will have its resistance reduced to that controlled by the modulus of rupture of the unit, which is several times less than the resistance which would be attained in the absence of the space. The use of a seat or edge bearing angle behind unreinforced masonry curtain walls or partitions does not significantly increase the strength of the member; however, if a joint space exists between the bottom of the roof slab and the top of the panel, the use of a bearing surface is desirable. Walls having a low thickness-to-height ratio may reach peak resistance before the maximum unit stress,  $f'_c$ , is reached. For this condition, the following expression for the resistance function up to the maximum value should be used.

$$R = \frac{8f'_c a}{h} (t-a-x) \text{ for } \epsilon E_m \leq f'_c$$

$$\text{Where: } x \doteq 0.5h \sin \theta + x_c; f_c = \frac{(x-x_c) E_m \epsilon_m}{t-x_c}$$

$$a = \frac{\epsilon L \cos (\phi - \theta) - h' + h}{2 \sin \theta \cos \theta}; \quad \epsilon = 1 - \frac{h'}{L \cos (\phi - \theta)}$$

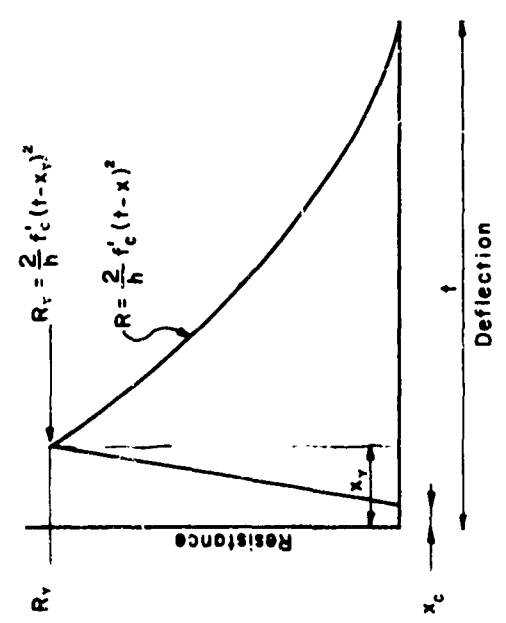
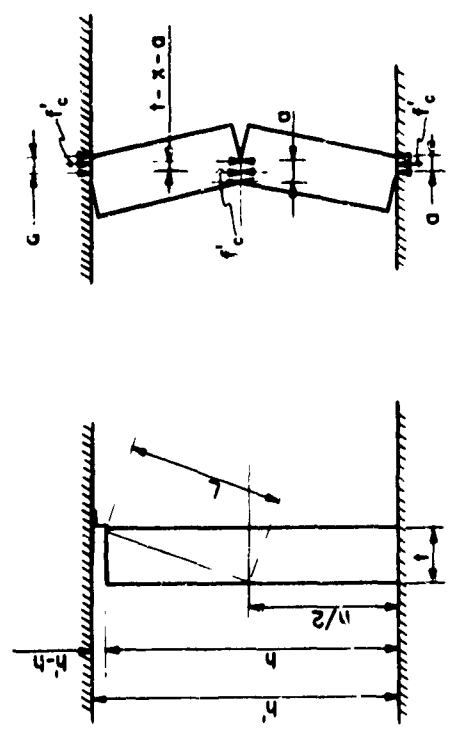
$\theta$  = angular rotation of wall

$$\phi = \arctan \frac{2t}{h}$$

After maximum resistance the resistance function may be approximated by substituting the value of compressive stress at maximum resistance for  $f'_c$  in the equations shown in Figures 3.37 and 3.38.

Resistance functions for reinforced concrete, reinforced masonry, corrugated metal, and corrugated transite members which were used in analyzing the test panels were de-

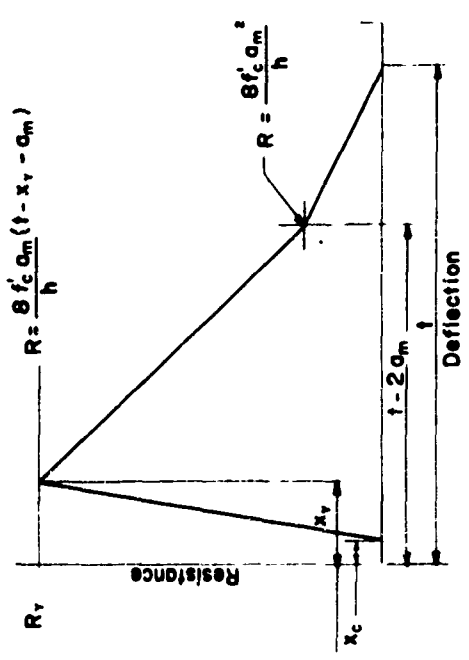
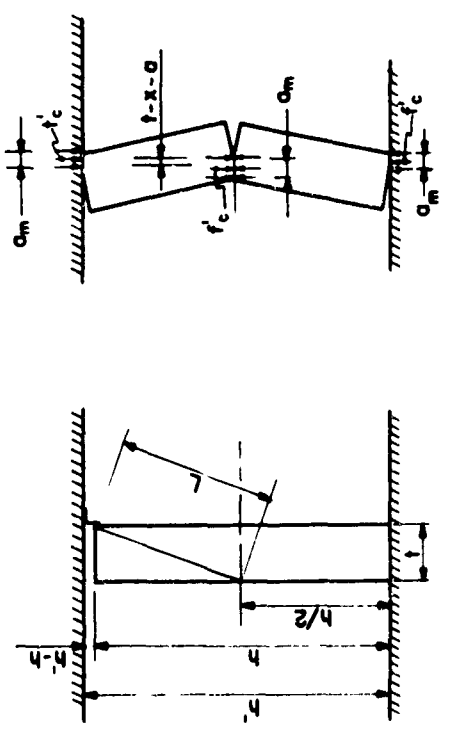




$$x_c = t - \sqrt{L^2 - 0.25(h')^2} ; x_v = \frac{(t - x_c)f'_c + x_c}{E_m \epsilon_m} ; \epsilon_m = \frac{L - 0.5h'}{L}$$

$E_m$  = modulus of elasticity of mortar unit  
 $f'_c$  = effective ultimate compressive stress of mortar unit

Fig. 3.37 Resistance Function for Unreinforced Solid Masonry Panel Rigid Supports



$$x_c = t - \sqrt{L^2 - 0.25(h')^2} ; x_v = \frac{(t - x_c)f'_c + x_c}{E_m \epsilon_m} ; \epsilon_m = \frac{L - 0.5h'}{L}$$

$E$  = modulus of elasticity of mortar unit  
 $f'_c$  = effective ultimate compressive stress of mortar unit  
 $a_m$  = hollow block flange thickness

Fig. 3.38 Resistance Function for Unreinforced Hollow Masonry Panel with Rigid Supports

veloped by Ammann and Whitney and Massachusetts Institute of Technology.

3. Interior partitions made up of plaster on metal lath (with or without studs) or some of the commonly used commercial types are capable of resisting somewhat greater loadings if they are tied in more securely to the walls and slabs.

4. Based upon the analytical resistance functions and the test results of the various curtain walls and interior partitions which were tested, the overpressures which the various types of windowless test panels may be expected to resist under a blast pressure loading similar to that of the test explosion may be estimated and is tabulated in Table 3.8. Since the test panels were all relatively quick acting, they would also be capable of resisting almost the same overpressures under blast loadings of longer duration.

Ten wall and seven roof panels representing several types of materials commonly used in conventional building construction (e.g., masonry, reinforced concrete, metal and wood siding, etc.) were included as part of the structures tests, and were positioned at three overpressure regions. The following conclusions concerning wall panel spans encountered in normal practice are included below for additional information and comparison.

Wall Panel	Estimated Allowable Overpressure on the Panel (psi)
8-inch windowless brick	9 or less
8-inch cinder block plus 4-inch brick	9 or less
8-inch and 12-inch cinder block	4 or less
Asbestos board over wood girts	less than 2
Corrugated sheet steel over steel girts	less than 2
Wood siding over plasterboard nailed to studs	less than 2

The upper bounds refer to the 8-foot 9-inch high by 13-foot 9-inch test panels which were of smaller size than most such construction met in practice. Considering all of the possible variables that may occur in the material strength, moduli and workmanship, the comparison of the above data with Table 3.8 is fair except for the hollow-block units. The relatively large discrepancies in the hollow-block results are probably due to comparably large compressive-strength differences of the types of units used (see Section 3.1) in the two test projects.

## REFERENCES

1. "Masonry Mortar Laboratory Test Results," Laboratory No. P220408; February 3, 1953; Silas Mason Company, Inc.; Unclassified.
2. "Report of Brick Tests," Laboratory No. P218288; October 30, 1952; Silas Mason Company, Inc.; Unclassified.
3. "Report of Tests on Hollow Load-Bearing Masonry Units," Laboratory No. 53-62; June 30, 1953; Unclassified.
4. "Concrete Test Cylinder Data"; January 21, 1953; Report No. 145, 3.29a Cell 18 Precast Panels; Silas Mason Company, Inc.; Unclassified.
5. Walker Bleakney; "The Diffraction of a Shock Wave around a Hollow Rectangular Block-Opening Facing Shock"; October 16, 1950; Princeton University, Department of Physics; Unclassified.
6. "Natural Frequency of Vibration Data"; RD680.
7. J. P. DenHartog; "Mechanical Vibrations"; 1940; McGraw-Hill Book Company, Inc.; Unclassified.